ARS National Biological Control Program, Proceedings of Workshop on Research Priorities

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PREFACE

E. G. King was assigned by E. B. Knipling, Associate Deputy Administrator, to serve on a special detail to the ARS National Program Staff (NPS) in 1987 "to develop an overall coordinated program to focus and strengthen ARS biological control research." The Research Priority Setting Meeting described in these proceedings is an outcome of this assignment. The assignment also included the identification of the ARS biological control resource base. Profiles of ARS Biological Control Scientists included in this document was an outcome of this investigation.

Biocontrol Working Groups have been formed by R. S. Soper, ARS National Program Leader for biological control research, effective April 1988. Their role will be to serve their areas of specialization and provide expert technical advice to the ARS National Program Staff on matters relating to biocontrol research and its effective utilization. Strategic planning on priorities identified in these proceedings will be a responsibility of the NPS Biocontrol Matrix Team, with the assistance of these groups.

This document has been prepared by E. G. King; J. R. Coulson; and the meeting secretary, R. J. Coleman, under the auspices of the ARS National Biological Control Program and R. S. Soper, ARS National Program Leader, Biocontrol.

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EXECUTIVE SUMMARY

The Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), National Biological Control Program (NBCP) was established to unify ARS biological control research under one program. For purposes of the Priority Setting Meeting, the NBCP was delineated by defining biological control as "management of natural enemies (predators, parasites, and pathogens of pests) and selected beneficial organisms (antagonists, competitors, and allelopaths) and their products to reduce pest populations and their effects."

The need for unifying, improving coordination, and expanding the use of biological agents for pest control is fully justified by (1) the public's concern over harmful pesticide residues in water and food, (2) the rate at which pesticides are being rendered obsolete by resistant pest populations, (3) acute and long-term effects of pesticides on nontarget organisms other than humans, including reduction of naturally occurring biological agent populations, and (4) depletion of non-renewable petroleum to produce chemical pesticides, as well as (5) increasing the profitability of farming.

The primary objective of the Planning Meeting was to establish the priority critical research needs (10 per discipline or area) that must be satisfied for rapid (within five years) expansion in the practical usage of biological agents for pest control in the USA. The meeting was attended by 30 federal scientists representing ARS, the USDA Animal and Plant Inspection Service (APHIS), the USDA Office of International Cooperation and Development (OICD), and the Environmental Protection Agency (EPA).

The meeting was structured to provide attendees with a common information base. Nineteen papers were presented on biological control of arthropod pests, weed and brush pests, foliar and soilborne diseases, and nematode pests. Introductory comments were made by the Administrator of ARS, T. B. Kinney, Associate Deputy Administrator, E. B. Knipling, and members of the ARS National Program Staff.

Attendees were then divided into three discipline areas (I. Insect, Mite, and Tick Pests; II. Terrestrial and Aquatic Weed/Brush Pests; and III. Foliar and Soilborne Diseases and Nematode Pests) to establish priority critical research needs in those areas, using the Nominal Group Technique.

Technology for mass propagation, harvesting, packaging, storage, and distribution and release, or application, for augmenting biological agent populations or their products, was viewed as high priority in each of the discipline areas. This research need was viewed as critical in support of APHIS programs as well

as ARS programs. Other critical research needs viewed as high priority across disciplines were "Systematics of biological agents" and "Genetic improvement through biotype selection, conventional crosses, and genetic engineering." The exploration for new, more effective biological agents for establishment in the USA was emphasized for control of arthropod pests and weed and brush pests. Maintenance of adequate capabilities for quarantine containment of biological agents emerged as an operational need, particularly the lack of a multi-purpose research containment facility at the Beltsville Agricultural Research Center.

Identification of the ARS resource base in biological control is essential to focusing research efforts on identified critical research needs. ARS biological control research was found to be housed in 73 units or laboratories, in 31 States, and France, Italy, Argentina and South Korea. It was being conducted by 218 scientists constituting 144 scientific years. About $20 million was being spent annually by ARS on biological control research. Development of a coordinated plan with a focus on scheduled events can/must be used to direct identified resources on priority critical research needs and events leading to goal attainment.

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PRIORITY CRITICAL RESEARCH NEEDS

I. Biological Control of Insect, Mite, and Tick Pests

1. Develop technology for mass propagation (*in vivo* and *in vitro*), harvesting, packaging, storage, and distribution of quality-assured biological agents for control of insect, mite, and tick pests by augmentative releases.

2. Increase the knowledge of the biology, ecology, and behavior of biological agents to more effectively use them in controlling insect, mite, and tick pests.

3. Continue support of overseas explorations and laboratories for importation of exotic biological agents to control insect, mite, and tick pests, and improve communication and cooperation between the domestic researchers and the overseas scientist/laboratory.

4. Maintain and increase support for taxonomic research on biological control agents of insect, mite, and tick pests emphasizing plant-feeding mites, lepidopterous larvae, fruit fly larvae, and spiders and ticks. Include research on morphologically-based and biotechnological methods for biosystematics, and on pest-host and larval-adult associations.

5. Develop pest management systems that enhance the survival and effectiveness of biological control agents by minimizing the use of chemical pesticides that are environmentally hazardous.

6. Develop technology for objectively selecting agroecosystems that lend themselves to cost-effective use of biological agents for control of insect, mite, and tick pests.

7. Develop the technology for application/release of biological agents and for maintaining their effectiveness in tests to assess the technical and economic feasibility of augmenting biological agent populations. Transfer the augmentation technology in selected commodities/areas where it is economically and operationally feasible.

8. Develop technology for species/biotype selection and genetic improvement (including genetic engineering) to enhance key attributes, e.g., pesticide resistance and climatic tolerance, for improving the effectiveness of augmented biological agents.

9. Develop cost-benefit analyses for successful projects that demonstrate the effectiveness of biological agents in improving production efficiency and environmental quality to accelerate the transfer of biological control technology.

10. Develop computer-based decision-making technology that makes explicit use of biological agent populations in making decisions for managing arthropod pests.

II. Biological Control of Terrestrial and Aquatic Weed and Brush Pests

1. Demonstrate/quantify efficacy of biocontrol agents.

A number of biocontrol agents have shown potential for the control of weeds. However, data are needed to quantify the level of control, number of insects and pathogen propagules needed to establish a population, level of stress needed to control the weed. This type of data would be useful in the decisions concerning our commitment of resources to the biocontrol agent and development of a release program by APHIS.

2. Host/biocontrol agent interactions.

Host-biocontrol agent interaction studies are needed in natural ecosystems. Emphasis should be on the effect of climate on weed-biocontrol agent interaction and on biocontrol agent establishment, plus ecophysiological and ecosystem studies.

3. Explore/discover/assess potential biocontrol agents/taxonomy.

Research is needed to discover new biocontrol agents for target weeds and to assess their potential. Continued development of our systematics capability is vital to this portion of the biocontrol program.

4. Process development.

Research is needed to develop the means of rearing or culturing biocontrol agents. In particular, the development of scale-up/process technology is needed to ensure the success of potential biocontrol pathogens.

5. Formulation/application development/dispersal.

One of the major hurdles in the development of commercialization of biocontrol agents is the lack of technology to disperse, apply, and formulate these agents. In particular, development of formulations and application technology for the use of pathogens to control weeds is needed.

6. Quarantine/containment facilities.

Quarantine facilities are vital to the continued success of the biocontrol program. Additional quarantine facilities have recently been completed by several States. Depending on the needs of the State scientists, access to these facilities for ARS scientists can become limited. The present and future quarantine needs of the biocontrol program should be assessed and a proposal developed to cover future needs. In addition, the Frederick foreign disease quarantine facility is the only one with full containment capability for exotic pathogens. The loss of this facility, either

through some natural catastophe or need from the Department of Defense, would severely impede our biocontrol program.

7. Environmental/population and integrated pest management models.

Models are needed to describe the natural enemy-weed population interactions and predict the development or establishment of biocontrol agents in the field. These models would serve to identify data gaps in our understanding of these interactions in the weed environment and eventually assist us in assessing the potential of a biocontrol agent.

8. Target selection.

Economic input is needed to assist in selecting suitable targets for biocontrol agents.

9. Directed mutagenesis/biotechnology.

Research is needed on directed mutagenesis and biotechnology to develop suitable biocontrol agents that would augment the current techniques of exploring for and discovering biocontrol agents in the field.

10. Supply of endangered or threatened species.

One of the present hurdles in completing the required prerelease host specificity tests is the supply of suitable numbers of endangered or threatened plant species that must be tested. Technology is needed to supply these plants through development of a source of seeds, vegetative propagation, and tissue culture.

III. Biological Control of Plant Pathogen and Nematode Pests

1. Determine the mechanisms by which beneficial microbes act upon pathogens. We know a few of these, e.g., antibiotics and cereal root diseases, the compound responsible for controlling peach fruit rots, and the mechanisms of biocontrol of Verticillium wilt and Sclorotinia disease; but most remain a mystery. Until we know what they are and where they exert their influence in the system, we cannot expect to enhance them nor their efficacy.

2. Improve dependability/reliability of treatments to control pests. Many of those that can be highly effective in one treatment do poorly in another "identical" situation for unknown reasons. Industry has expressed reluctance to commercialize biorationals because of erratic performance. There is a need to determine the basis for this performance.

3. Develop large scale production, formulation, and application capabilities for many of the known effective biocontrol microbes in order to do field scale evaluations that will convince the private sector to adopt these disease control methods. We now have very little work - but relatively good success - along these lines.

4. Develop genetic alteration technology of promising microbes to allow their use in combination with chemicals, enhance efficacy, improve shelf life and scope of activity against several pathogens or on many crop hosts.

5. Develop one or more "champion" beneficial microbes as widely adopted examples to set precedents for industry and growers to prove that biorationals are worthy of the cost of registration and commercialization because they can be cost competitive with chemicals, effective, and safe.

6. Discover and identify beneficial microbes for the control of major pest problems such as soybean cyst nematode and certain leaf diseases for which there are yet no promising biorationals.

7. There are known examples of highly successful naturally occurring biocontrol of crop diseases and nematodes in restricted areas. The most susceptible varieties are grown in infested soils but disease does not develop. Nothing is known as to why these systems work. Examine disease suppressive soils and determine factors responsible for "natural" successes.

8. Beneficial microbes may exert their influence on the surface of the roots, leaf or fruit by displacing harmless or harmful microbes. Determine factors that cause microbes to adhere to plant surfaces and proliferate so that beneficials can be favored. Current technology is largely "chance" adherence to host determinant sites because microbe interactions and ecology are poorly understood.

9. Develop models for grower use of beneficials bringing together climatological, microclimate, economic, and biological data that will allow decision making for maximizing usefulness and effectiveness of beneficials.

10. Develop controlled/directed multiple gene transfer technology among higher plants for the purpose of producing engineered resistance to major crop pathogens and nematodes.

To facilitate these critical areas of research the team recognized the need for strong supporting activities such as the ARS Documentation Center, containment research facilities for work on foreign and genetically engineered microbes as required by new Federal regulations, and improved systematics capabilities.

MINUTES

Participants in the Research Priority Setting Meeting, ARS National Biological Control Program (NBCP) convened at the Bioscience Building Conference Room in Beltsville, MD, on July 14-15, 1987 (See Appendix for meeting agenda). Objectives for this meeting and future events were likened to those developed for the ARS National Heliothis Suppression Program: 1) identify resource base of scientists; 2) review status of technology; 3) formulate critical research needs; 4) conduct priority ranking of critical research needs; 5) conduct critical path analyses using program and evaluation review techniques (PERT); 6) identify bottlenecks; and 7) establish action areas.

Dr. E. B. Knipling welcomed participants to the meeting and stated his hopes that biological control will have a stronger focus within ARS and that priorities will be on solving problems using a task, goal, and results orientation. He emphasized the importance of positive results and need for delivery of practical biological control systems. Present emphasis on biological control and its higher priority in the future may entail possible budgetary increases and funding shifts. ARS views the need for alternatives to chemical control as based on concern for ground water quality, food safety (toxic residues), non-target effects, high costs of chemical control technology, high costs in developing and registering new compounds, and pest resistance to chemical compounds.

The National Program Staff (NPS) will give high priority to biological control, as will APHIS, and the NPS intends to give high visibility to the new national program leader for biological control. Dr. Knipling stated that private industry is also interested in biological control because they realize that they are in the business of pest control, not just chemical control.

The resource data base of ARS biological control scientists has revealed some surprises. Biological control research is scattered and fragmented, and cuts across numerous areas. Dr. Knipling noted that ARS may be working on too many problems, and perhaps redirecting present resources on fewer problems with more critical mass, especially in those areas most amenable to biological control, may be necessary. Also, more follow-up is needed on research projects, i.e., development of sound pilot tests, incentive money to private industry, etc.

Dr. Knipling stated that the overseas biological control laboratories must address domestic issues and means must be developed for better cooperation with domestic laboratories. He noted that researchers should not be limited in their approach to biological control. Perhaps there should be a broader definition with less emphasis on classical biocontrol and greater use of newer technology.

In the subsequent discussion, a comparison of the relative "delivery" rates for chemical pesticides and biological agents was made. It was estimated that the time required to develop and market a chemical pesticide was about 10 years, with a corresponding estimate of 5-7 years given for an introduced biological control agent to become effective. Emphasis on working with user groups, i.e., technology transfer, such as private industry, State agencies (Departments of Agriculture, etc.) and APHIS was reiterated.

Dr. Larry Christy, Acting NPS Biological Control Team Leader, stated that the EPA plans to bring FIFRA into line with the Endangered Species Act. This could greatly restrict or eliminate the use of presently registered compounds for pest control; thus, making it more important to develop biological control systems. However, he expressed a need for caution in promoting the use of biological control agents to producers as it will not be possible to displace all chemical usage.

Dr. Julius Menn commented that good opportunities exist for delivering biological control systems, and one catalyst will be development of resistance to insecticides such as the pyrethroids. He noted that the corn rootworm in corn is controlled primarily by preventative treatments with organophosphates. This use constitutes 50% of the insecticides used in the USA. So the corn rootworm should be a high priority target for biocontrol implementation. Gypsy moth control also relies on biocontrol agents, and possibilities for fruit flies should be examined. Dr. Menn emphasized the importance of developing genetic sexing systems for use in autocidal programs for controlling the carrot fly, Heliothis, boll weevil, and fruit flies. Manipulation of the genome of beneficial insects and improving the virulence and biotic potential of microbials should also receive more effort. He also noted the importance of future direction after a successful pilot test and that we must begin to address the scale-up effort and costs and wherever funds are available.

Dr. Howard Waterworth noted that the first patents for biological control of plant pathogens are held by ARS scientists. He challenged those present to recognize and consider a broader definition of biological control. Ruxton Villet reiterated the need for ARS to develop products for utilization by the private sector.

Dr. Jim Cook's presentation was based on the report "Biological Control in Managed Ecosystems" (see Paper 1, Appendix, p. 22) which had been presented to the Office of Science and Technology Policy. A key point was that biological control should be the primary (not necessarily the only) method of pest control. He provided a broad definition of biological control: "The use of natural or modified

organisms, genes, or gene products to reduce the effects of undesirable organisms (pests), and to favor desirable organisms such as crops, trees, animals, and beneficial insects and microorganisms". This definition was much broader than the one used for this meeting.

Dr. Cook discussed the three biocontrol strategies as given in his paper and the three components of biocontrol in relation to the strategies. He gave examples of these which are included in Table 2 of his published report. He also noted the three methods of biological control:

1) occasional introduction of organisms or genes ["classical biological control" as defined by entomologists]

2) maximize biological control by cultural methods ["conservation approach" to biological control]

3) repeated introductions ["augmentative" approach]

Cook emphasized three needs for biological control: 1) more basic research; 2) the solution of complex problems through interdisciplinary research; and 3) finding ways of moving research results from the laboratory to the field. Discussion afterward centered around the definition of biological control and how its definition could impact funding and direction of future research, with the possibility that a narrow definition may have a negative (or limited) effect on research. Dr. Knipling advised the group not to be too concerned about the scope of the definition at this point.

Dr. Ed King (see Paper 3, Appendix, p. 26) restated the five imperatives for biological control as stated in his original memo to the core group: 1) reduce pesticide residues in groundwater, soil, air, and food; 2) increase production efficiency; 3) develop nonchemical control procedures for resistant pest populations; 4) reduce effects of pesticides on nontarget organisms; and 5) conserve energy by replacing non-renewable, petroleum-based pesticides with biological control agents. The working definition of biological control used in this meeting was "management of natural enemies (predators, parasites, and pathogens of pests) and selected beneficial organisms (antagonists, competitors, and allelopaths) and their products to reduce pest populations and their effects". He noted that a number of priorities and recommendations for biological control were contained in the proceedings of the 1984 Work Conference on Biological Control held in Laurel, Maryland. Other recent resource documents were cited.

King described a recently completed survey of ARS scientists researching biological control. The survey instrument was distributed to 360 ARS scientists whose assignment had been identified as possibly including biological control research. It consisted of 10 parts: Scientist Name; Laboratory/Unit; Location; Phone Number; CRIS Work Unit(s); Control Approach(es); Research Area(s); Protected Commodity(ies)/Area(s); Control Agent(s) Researched; and Research Activity Description. Results of the survey are described in detail in Paper 3, Appendix, p. 26, and individual responses are summarized in the section "Profiles of ARS Biological Control Scientists".

ARS biological control research was being conducted by 218 scientists constituting 144 scientific years (SY), in 176 CRIS Work Units. This research was housed in 73 units or laboratories, in 31 states, and in France, Italy, Argentina, and South Korea. Biological control research was conducted in five of six objectives in the ARS Strategic Plan but primarily in three objectives: Plant Productivity; Animal Productivity; and Commodity Conversion and Delivery (Post Harvest). Nine major Strategic Plan Codes were involved (Table 1).

Table 1.
Major ARS strategic plan codes which include components of biological control research.

Objective 2. Plant Productivity (103 SY)

1/3 in E 2.4.09 (53.1 SY)

E 2.2.01

E 2.2.05

E 2.4.02

E 2.4.03

E 2.4.06

E 2.4.07

Objective 3. Animal Productivity

AE 3.5 (10.1 SY)

Objective 4. Commodity Conversion and Delivery (8.7 SY)

AE 4.3 (8.7 SY)

Other E 2.1.02 (12 SY)

(In all, components of biocontrol research are found in 5 of the 6 ARS Objectives, 10 Approach Elements, 25 Elements, 29 Problems, and 82 Subproblems. See ARS Strategic Plan.)

The biological control approach containing the greatest scientific effort (148 scientists, 77 SY) was augmentation, i.e., the propagation and release or application of biological control agents, followed (84 scientists, 43 SY) by classical biological control, i.e., the exploration, importation, release, and evaluation of exotic biological control agents (Table 2). The research effort on biological agents for control of arthropod pests, and arthropods controlling weed and brush pests, predominated with 110 out of 144 SY. Of these, over half of the ARS biological control effort is dedicated to protecting plants from insects and mites. Twenty-five scientific years (40 scientists) research biological control of weeds, but this includes use of phytophagous arthropods and microbial agents. The smallest effort (1.1 SY) was directed toward biologically controlling nematodes (Table 2). Insofar as research areas, most scientists are involved in the release or application and evaluation of biological control agents and their developmental biology and population processes as well as systematics (Table 3).

Discussion centered on whether figures on SY effort should be limited to those showing a "critical mass" which would be a percentage of full time vs. less than full time SYs devoted to biological control. There was some concern that using figures showing less than 0.25 or even 0.50 SY might artificially inflate the total critical mass of biocontrol researchers in ARS.

Dr. Dave Kincaid (see summary, p. 10) noted that the mission of overseas laboratories is to support domestic research laboratories. He discussed the programs of the four overseas biological control laboratories, noting that the contract insect pathologist position at the EPL is to be made an ARS position (at least temporarily) and that the U.S. SY position at the laboratory in Argentina is not to be filled due to our State Department's restrictions on overseas positions. Budgetary constraints will require more contract research, cooperative agreements, and grants at these overseas laboratories. More interaction with CIBC will be developed. Opportunites are also available through the Spain Program and Special Foreign Currency Program (Costa Rica, Taiwan, and Yugoslavia) of OICD.

Jack Coulson gave the background and described the programs of the Documentation Center (see Paper 2, Appendix, p. 23). He noted that 35 percent of our insect pests and most of our major weed pests are introduced pests. These pests were most amenable to the classical biological control approach. The biological control survey just conducted will be used to

Table 2.
ARS scientists conducting research on biological control to protect selected commodities or areas from pests within control approaches

	Control Approach (SYs)[a]			Total	
Commodity/Area	Classical	Conservation	Augmentation	SYs	Scientists[b]
Plants from Insects/Mites	18.0	14.2	41.8	74.0	120
Plants from Weeds/Brush	15.9	1.3	6.8	24.9	40
Plants from Disease	0.6	4.2	14.8	19.7	36
Plants from Nematodes	0.1	0.3	0.7	1.1	2
Post-Harvest Products from Insects/Mites	0.6	0.6	6.5	7.7	16
Man/Animals from Insects/Mites/Ticks	6.1	1.1	4.7	11.9	22
Aquatic Resource	2.1	0.0	0.1	2.2	3
Post Harvest Products from Pathogens	0.0	0.3	1.8	2.1	5
TOTAL SYs	43.4	22.0	77.2	143.5	
TOTAL SCIENTISTS[b]	84	74	148		218

[a] SYs derived by formula Control Approach SYn * Commodity SYn/Total Commodity SY.
[b] Total scientists exceeds 218 because scientists often conduct research across biological control agents and control approaches.

Table 3.
ARS scientists conducting research on biological control by research area within control approach

Research Areas	Control Approach (SYs)[a]			Total	
	Classical	Conservation	Augmentation	SYs	Scientists[b]
Systematics	4.3	6.1	4.4	14.9	36
Foreign Exploration	6.7	0.1	0.5	7.3	31
Quarantine/Clearance	6.6	0.0	0.3	6.9	24
Release/Evaluation	10.1	1.1	6.7	17.9	64
Developmental Biology	6.0	2.0	18.5	26.5	101
Population Processes	4.6	5.9	10.2	20.8	82
Modeling/Systems Analysis	0.8	1.5	2.0	4.4	24
Pesticide/BC Agent Interaction	0.9	1.2	3.5	5.7	34
Semiochemical	0.5	0.5	2.2	3.2	14
Propagation	1.6	0.4	8.0	10.0	42
Genetic Improvement	0.1	1.1	8.4	9.7	25
Application Systems	0.7	0.6	7.8	9.1	46
Economic Analyses	0.2	0.0	0.2	0.4	3
Allelopathy	0.0	1.0	0.2	2.1	7
Total SYs	43.3	22.0	77.2	143.5	
Total Scientists[b]	84	74	148		

[a]SYs derived by formula Control Approach SYn * Research Area SYn/Total Research Area SY.
[b]Total scientists exceed 218 because scientists often conduct research across research areas and control approaches.

update the Biological Control Information Document which will be published on a biennial basis rather than annually as in the past. The first ROBO publication (for 1981 releases) will be available early in 1988. He made a plea that all reports, reprints, and copies of correspondence relating to biological control research be supplied to the Documentation Center in order to keep the Center files current.

Dr. Lloyd Knutson stated that research on the systematics of fungi, higher plants, and nematodes is now included in the research programs of the Biosystematics and Beneficial Insects Institute. The Institute in the past has been largely limited to research on arthropods. He noted the importance of systematics to biological control and distributed copies of his 1981 paper for the BARC Symposium 5, "Symbiosis of Biosystematics and Biological Control" and other materials. He also pointed out some of the specific problems in meeting research needs in the Institute and a number of critical research needs in biosystematics. See the summary of his presentation, p. 10.

The need for obtaining identifications of microbial organisms for biological control was expressed during the discussion. Authoritative identification capabilities are available; however, the means for accessing them are unknown to many ARS biological control workers. Also, the need for increased capability for identifying weeds, especially closely related species, was discussed.

Dr. Jack Drea noted that one problem facing classical biological control of insects and mites is the perception that the level of success of this approach has not been high. He questioned whether this perception was due to inadequate publicity for the successes actually obtained by classical biological control or whether the achievements of this approach have been adversely diluted by the many other approaches presently called "biological control".

Among the five major problems discussed in Drea's presentation (see summary, p. 11) are that ARS quarantine capabilities are being reduced nationwide, that no weed quarantine capabilites exist in the Northeast and that there is a need for a multi-purpose research quarantine facility at BARC. He noted that more emphasis on field studies vs. laboratory studies in overseas locations is needed.

Dr. Terry Kinney stated that presently he knows of no area within ARS more important than biological control research. He stated that it is incorrect to think of biological control solely as "non-chemical control", emphasizing

that not only do we need biological control systems that can minimize adverse environmental impacts, but that they also be economically feasible and represent long term methods of pest control. He stressed the need for technology transfer or technology implementation. Nevertheless, he stated that funding will probably not match our enthusiasm for biological control. It must be determined how present resources can be better utilized which will entail close scrutiny of low priority projects. Dr. Kinney noted that it is important that we define the ARS National Biological Control Program so that our objectives and progress can be readily identified.

Lloyd Andres noted that weeds caused an annual loss of over seven billion dollars a year in the U.S. He described the current research program on classical biological control of terrestrial weeds (see his summary, p. 12), noting, for example, that six insects have now been introduced for control of leafy spurge. Among the problems and critical research needs discussed were problems involved in screening a number of exotic biocontrol agents and locating and culturing native plants needed in the screening process. In this respect, personnel for maintenance of at least a portion of the Albany, CA quarantine facility (after remaining personnel are relocated to Bozeman, MT) is critical. Also, more research on plant taxonomy is needed for identification of biotypes and to help track exotic origins of U.S. weed populations. The yellowstar thistle project presents examples of these needs. There is also a need for research on diets for weed insects and on weed ecosystem dynamics.

There was considerable discussion of the consequences of the loss of the California quarantine facility. This was of great concern to the APHIS representatives at the meeting.

Dr. Ted Center discussed his current research situation concerning aquatic weeds noting that no economic evaluation has ever been done for the highly successful alligatorweed and waterhyacinth programs. He expressed a need for research on the taxonomy of some of the insects involved in some of the current projects and noted problems in the logistics and coordination of classical biocontrol programs (see summary, p. 12). Some of the current target weeds are hydrilla, waterlettuce, and Melaleuca. In the aquatic weed programs, the U.S. Corp of Engineers has played the same role as APHIS in the dissemination of imported natural enemies.

Dr. Bill Bruckart noted that emphasis of research at Frederick, MD, is directed toward evaluation of exotic plant pathogens for biological control of rangeland weeds. Of the 30 such weeds identified at the 1984 Conference, 26 are introduced species. Therefore, the Rome laboratory is very important to the research program to advance the use of exotic plant pathogens for weed control. He noted that the Frederick laboratory is not involved in the mycoherbicide approach for weed control. There is a new SY at this location. See the list of critical research needs in the summary, p. 12). These included overseas exploration and research (study impact of plant pathogens on target species *in situ*) and research on pathogen evaluation and improvement.

Dr. George Papavizas discussed the current research of the Soilborne Diseases Laboratory (see summary, p. 13). He stressed the need to develop biocontrol formulations and applications acceptable to industry, and to expand cooperative efforts with industry to produce and register effective biocontrol formulations. He noted that no foreign exploration or genetic engineering is needed in the biocontrol of plant pathogens area. Many local biocontrol agents are available for research. He listed a number of critical research needs among which was the need to discover the biochemical bases of biological control using fungi and other agents and research on the mechanism of action of biocontrol agents in plant pathology.

Dr. Harvey Spurr discussed the importance of and problems in foliar disease biocontrol (see summary, p. 14). He noted that this approach has been hindered by unpredictable field results. He noted that modeling was very important because the epidemiology of foliar diseases is poorly known. He discussed a computer simulation model for *Cercospora* leafspot of peanut for which bacteria (*Pseudomonas* and B.t.) are being used as control agents for this disease. He stated that in general foliar fungicides produced no deleterious effects on bacteria used for biocontrol. Among the critical research needs was the expansion of funding and an increase in the number of permanent SYs for the biocontrol of foliar pathogens.

Dr. Robin Huettel discussed the importance and status of plant parasitic nematology (see summary, p. 14) noting that research in this area only began in 1943. It has become imperative to develop biocontrol for plant parasitic nematodes because only seven of 23 registered nematicides available in 1980 can still be used. No alternative controls are yet available. Companies producing nematicides are greatly interested in potential biocontrol products for nematode control. Predaceous fungi are more promising than are nematode- trapping fungi for control of plant nematodes; host specificity is a problem in both groups. There is a need to develop fungicide-resistant strains of predaceous fungi. Currently only one SY is involved in researching biocontrol of plant nematodes, specifically on bacterial agents. There is a need for an additional SY to study fungal agents.

Huettel listed the characteristics of an ideal biological agent for nematode control: 1) survival in the soil in active and inactive stages, 2) high probability of host contact, 3) easily propagated (this is a major problem), 4) amenable to packaging and application, 5) host specific, 6) safe, 7) active under appropriate environments, and 8) economical.

Dr. Dick Patterson (see summary, p. 15) noted that the Department of Defense mandates research on control of insects affecting humans. Insects, mites, and ticks affecting livestock cause an annual loss to the livestock industry in excess of four billion dollars. Flies are the main pests (four species; all introduced). Other pests include ticks (which offer little promise for biocontrol), cockroaches, mosquitoes, and fire ants. Some reasons for developing biocontrol of human and animal pests are 1) very few effective pesticides, 2) rapid development of resistance to pesticides, 3) pesticide residues in animal products, 4) changing production systems (e.g., rolled hay bales, higher densities of caged/penned livestock), 5) greater awareness of ecology and effects of pest management practices on the environment, and 6) cost-efficiency. However, he noted that single control systems are not the answer for control of pests of humans and animals.

Patterson listed some of the critical research needs which include for 1) flies: information on the interrelationships of the various natural enemies and competitors, standardized methods for evaluating parasites, and research on pathogens; 2) mosquitoes: research on predators and pathogen efficiency which may include genetic manipulation; 3) fire ants: research on ecology in their native habitat (South America); 4) cockroaches: research on pathogens. He noted that new quarantine facilites are being developed at Gainesville, FL for the study of exotic mosquitoes and biological control.

Dr. Tim Wong stated that he was not a specialist on stored product insects. Consequently, his discussion was restricted to the fruit fly research in Hawaii where sterile males and parasitoids are being released on Maui against the medfly. He noted that fruit production in Hawaii is limited to only papaya because of the fruit fly complex (medfly does not attack pineapple). A new fruit fly, the Malayasian or chili pepper fly, entered Hawaii in 1983 and is not yet a serious pest. There are a number of problems involved in the laboratory culture of parasitoids which are reflected in the list of critical needs in his presentation.

Dr. Chuck Quimby's presentation (see summary, p. 15) dealt with the program at Stoneville, MS, and the use of pathogens in augmentative biocontrol of weeds in row crops. He presented several tables noting the number of scientists involved, partitioned by state, disciplines, and strategic plan codes at the problem level. He also provided a list of research needs, the more important being research on fermentation/production of inoculum.

Dr. Carlo Ignoffo discussed the control of insects and mites with pathogenic microorganisms (see summary, p. 16), including the status of the science in both industry and ARS. He provided a table of registered microbial pesticides, of which, only a few have been commercially successful. The critical research needs in this area are listed in his presentation. He emphasized the need for a tailored selection of the appropriate pathogen, pest, and ecosystem for research.

During subsequent discussion the question was raised as to whether ARS had selected the correct targets and pathogens for developing microbial pesticides. It was noted that there is a need to define the user group (e.g., APHIS, commercial concerns, etc.) when initiating research in this area. It was also pointed out that marketability should not be the major or only criterion in research on pathogens for control of insect and mites.

Dr. Richard Soper provided a brief report concerning the augmentation of insect and mite pathogens as components in integrated pest management and a list of critical research needs, one of which was the establishment and integration of a repository for arthropod pathogens into the National Germplasm system.

Dr. Harry Gross discussed the propagation and release of predators and parasites (see summary, p. 17) for controlling insect and mite pests of crops. He noted that the production of quality entomophages via <u>in vitro</u> methods would immediately increase the rate of adoption and likely frequency of success of the augmentation approach to biological control. Among the other critical research needs he discussed were refinement of criteria for the selection and prioritization of species for augmentation and the integration of entomophage augmentation with other management strategies.

Dr. Chuck Wilson noted (see summary, p. 17) that post-harvest loss in fruits, nuts, and vegetables amounted to about 25 percent. He discussed the development of biocontrol in this area, noting that one antagonist (<u>Bacillus subtilis</u>), which effectively controls brown rot of peaches, is about to be patented. He then discussed five critical research needs in this area.

Dr. Bob Hedlund distributed lists of active Special Foreign Currency Research Projects on biological control of weeds, insects, and plant pathogens and biocontrol projects under the BARD, Spanish, and Collaborative Research Programs. He discussed the various programs administered by OICD (see the Documentation Center's Biological Control Information Document, pp. 85-86). He stated that 99 percent of the proposals came from foreign scientists and that OICD was now accepting pre-proposals. He also stated that U.S. scientists should be encouraged to develop proposals and identify cooperators in foreign countries.

He noted that there were no longer any excess currency countries with appropriately competent scientists for collaborative research. There are currently no funds in Pakistan. There is a U.S.-India Fund, with funding controlled by the U.S. State Department. The State Department also provides U.S. funding for Joint Board

Projects in Yugoslavia. Poland has been reopened recently with nine new projects administered under a new Polish-U.S. act. There are also matching-funds projects in Taiwan and a small program in Costa Rica. He noted that Australia is qualified for a binational agreement.

Dr. Gary Cunningham discussed the background on APHIS's biocontrol implementation programs which are currently funded at $3.5 million per year (see summary, p. 18). He noted that APHIS relies heavily on its sister agencies (particularly ARS) to develop projects to the point of implementation, and pointed out the recent joint APHIS-ARS honor award for the development and implementation of biological control of the alfalfa weevil as an example. He discussed briefly the activities of the three APHIS biocontrol locations: Mission, TX; Niles, MI; and Bozeman, MT. Cunningham expressed concern over the move of the Albany, CA quarantine facility to Bozeman, MT, and its potential impact on the western regional quarantine capabilites in ARS. He noted the six current APHIS projects and five approved proposals. APHIS-PPQ submits Annual Research Needs to ARS. Among the 22 urgent needs for fiscal year 1989 there are four biocontrol research needs. Among the 23 moderately urgent needs there are nine that pertain to biological control and of the 15 routine needs, four pertain to biological control.

National Program Leader staff members were identified to moderate sessions which would employ the Nominal Group Technique to identify and produce a ranking of ten Priority Critical Research Needs for each of the three main components of biological control research: Larry Christy, biological control of weeds and brush; Howard Waterworth, biological control of plant pathogens and nematodes; and Ed King, biological control of insects, mites, and ticks. These sessions involved listing and ranking those critical research needs which must be individually satisfied before a specific approach that includes biological control agents may be used to suppress pests.

The Priority Critical Research Needs are listed on pages 1 (I. Biological control of insect, mite, and tick pests), 1-2 (II. Biological control of terrestrial and aquatic weed and brush pests), and 2 (III. Biological control of plant pathogens and nematode pests). A complete list of research needs developed by participants in the section for biological control of insect, mite, and tick pests can be found in Appendix, pp. 30-31.

Technology for mass propagation, harvesting, packaging, storage, and distribution and release, or application, for augmentation of biological agent populations was viewed as high priority in each of the discipline areas (I. 1,7; II. 4,5; and III. 3). Other critical research needs viewed as high priority in each of the three disciplines were systematics of the biological agents and genetic improvement through biotype selection, conventional crosses, or genetic engineering. Exploration, importation, and release and evaluation of exotic biological agents were emphasized only for the control of arthropods (I) and using arthropods for the control of weed and brush pests (II). In this vein, maintenance of capability for quarantining biological agents (particularly arthropods attacking weeds) on the west coast, as well as central and eastern U.S., emerged as an operational need. The lack of a multi-purpose containment facility in the Beltsville Agricultural Research Center was often cited as an impediment to conduct of biological control research.

The meeting was concluded with a discussion of possible future events which could entail the application of the Priority Critical Research Needs to selected "champion" biological agents, pest species, and commodities/areas protected. Core group members of this meeting could be assigned the task of conducting critical path analyses which would be used to identify bottlenecks or impasses and begin to refocus and redirect resources to establish critical masses for solving problems.

Note: Biological Control Working groups are now being formed as an advisory component of the ARS National Biological Control Program. Each group consists of specialists providing analysis, data, and advice on biocontrol within a specific area of research; e.g., "Augmentation, Classical, and Conservation Biocontrol Working Group", and "Microbial Biocontrol Working Group".

SUMMARIES OF PRESENTATIONS OF MEETING PARTICIPANTS

ARS Overseas Locations

D. R. Kincaid

The overseas activities of ARS are carried out at five locations, four of which are on biocontrol. These are:

Buenos Aires, Argentina -- The mission of the Biological Control of Weeds Laboratory - South America is to search for and test biological agents in southern South America and ship them to the U.S. for the control of weeds and insect pests. Research emphasis includes: (1) determining the geographical distribution and phenology of the pest species in South America; (2) finding promising natural enemies of the pest species; (3) determining the biology and ecology of these natural enemies and evaluating their potential effectiveness if introduced; (4) determining the host range and probable safety of the natural enemies if introduced; and (5) after approval from the corresponding U.S. authorities, to collect, colonize and ship the natural enemies to quarantine stations in the U.S. Specific current subjects are: rangeland weeds, southeastern pasture and crop weeds, and cow-dung breeding flies. A new effort is being started on biological control of the fire ants. The laboratory will accommodate a project of 2-3 years duration to survey for pathogens, parasites, predators and inquilines in cooperation with the Imported Fire Ant (IFA) Research Unit at Gainesville. Staff consists of a Foreign Service National (FSN) Officer in Charge, five FSN employees and three persons on contract. The annual budget is $152,000.

Rome, Italy -- The mission of the Biological Control of Weeds Laboratory - Europe is directed towards the development of biological control of U.S. weeds of foreign origin, utilizing parasites, predators or pathogens for weed control. Target weeds for which natural enemies are being sought are yellow starthistle, leafy spurge, diffuse, spotted and Russian knapweed, and musk thistle. The Rome Laboratory is comprised of an American Director, five FSN specialists/assistants, and three support staff. A field site at Thessaloniki, Greece, has one research entomologist and a contract assistant. The annual budget is $551,000.

Seoul, Republic of Korea -- The mission of the Asian Parasite Laboratory is to conduct research on biological control agents in the vicinity of the 35 degree latitude of Asia and to ship promising organisms to the United States for biological control of pests. Immediate goals of the research program are to continue the collections and shipments of parasites, predators, and pathogens for control of organisms listed as priority. These include, but are not limited to gypsy moth, Mexican bean beetle, chestnut gall wasp, Japanese beetle, European corn borer, and Apple ermine moth. Research on Japanese beetle ecology and pathology, gypsy moth viruses, etc., will continue. Staff consists of an American Director and four FSN employees. The annual budget is $152,000.

Behoust, France -- The mission of the European parasite Laboratory is to assist in the successful introduction into the U.S. of natural enemies or pathogens from Europe to control exotic or native pests of American agriculture. Collection and shipment of natural enemies to the U.S. is an essential part of this mission. In addition, research is conducted to obtain information on the biology, ecology, rearing, behavior or pathology which are essential to the success of individual projects. Current target insects are asparagus beetle, *Empoasca fabae*, *Heliothis* spp., *Lygus* spp., *Nezara viridula*, filth flies, and the areas of pathology, semiochemicals, and insect rearing. Two new CRIS units have been developed: "Biology, Ecology, Collection and Rearing of Natural Enemies of Insect Pests of American Agriculture" and "Pathology and Behavior of Insect Pests and Their Natural Enemies to Promote Biocontrol of Insect Pests in the U.S." Staff consists of three American positions, eight FSN employees and three contract employees. The annual budget is $822,000.

Systematics of Biological Control Agents, Pests, and Non-Target Organisms

L. V. Knutson

Problem Description and Importance -- National biological control research and action programs both require a diverse array of systematics research and services for all of the organisms involved. Specific systematics needs are known for on-line projects but specific systematics needs over the next several years and beyond are largely unpredictable. The longer range needs will depend on the target pests and control agents _to be_ selected, and this selection will depend _largely_ on the new pests that will become established. For these and other continuing needs (e.g., quarantine, regulatory, and survey programs) systematics capability covering the widest possible breadth of organisms must be maintained.

Systematics support for biological control is needed for two fundamental reasons: (1) practical-operational aspects, and (2) scientific reliability. Specifically, systematics information is needed: (1) to provide authoritative identification of the target pest species; (2) for access to the literature and for consistent, world-wide communication; (3) to enable authoritative documentation of the pests, biological control agents, and non-target organisms in publications and databases; (4) to estimate prey/host ranges for selection of the best biological control

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Copies of complete presentations are available from the ARS Biological Control Documentation Center, Beltsville, MD. See Appendix for presentations of R. J. Cook, E. G. King, and J. R. Coulson.

agents and to predict whether or not an introduced biological control agent will move onto a non-target host; (5) to decide where, geographically, to explore for biological control agents; (6) to predict micro-habitats and whether or not an ecological niche is filled or vacant; (7) to predict phenology, i.e., when to search for the biological control agent and when to introduce it; and (8) to predict the existence of natural enemies of biological control agents.

Status of Science and Technology -- The critical lack of systematics knowledge and human resources in systematics has been well described by many biological control scientists and other users (as well as systematists themselves) during the past decades.

Technologies to produce predictive classifications and to provide identifications have improved greatly over the past twenty years. However, for the past 230 years morphological characters have served as the primary basis of systematics research and services. Systematists, therefore, have developed a detailed understanding of these character systems. Furthermore, most of the specimens that require identification cannot be maintained in a living condition. For these reasons it is likely that at least 75% of systematics research on most groups of organisms over the next 50 years will be based on morphological character systems. Although we now have methodologies for solving problems (especially of species and biotype characterizations) that have been refractive to morphological methods these methods are expensive to develop and implement, and more time consuming. Despite biotechnological advances, morphological methods are usually so vastly superior in terms of costs in time and money that they demand to be used, wherever appropriate.

Critical Research Needs --

(1) Systematics research, identification capability, and associated information for on-line biological control projects.

(2) Long-term research in selected, high-priority biological control agent, pest, and non-target groups where it is highly likely that information will be required in the future.

(3) Further development of new research methodologies.

(4) Special research needs.

(a) improve first-line identification capabilities (collections, literature, and training of staff) in overseas ARS labs.

(b) continue biosystematic services for countries outside the U.S., especially Latin America.

(c) development of computer applications.

(d) development of expert systems.

Biological Control of Insect and Mite Pests by Exploration, Importation, and Release of Exotic Natural Enemies

J. J. Drea

Problem Description and Importance -- Within ARS, there is a perception that classical biological control has not maintained a satisfactory level of success. This is not because of the actual lack of successes, but instead may be due to the lack of adequate publicity for the successes obtained or that the concept of biological control has become so all-encompassing that the achievements of classical biological control have been adversely diluted. Although 218 researchers within ARS have been identified with biological control only 12 scientists in classical biological control are on a full-time basis with 10 on a 0.5-0.9 SY basis. Problems of major importance are: (1) reduced level of quarantine capabilities for biological control throughout ARS will have an impact on ARS with repercussions extending to national and state programs; (2) the establishment of a 75% research-25% service ratio at the European Parasite Laboratory in France has diminished the output of that facility; (3) the lack of any quarantine or research containment capabilities at the Beltsville Agricultural Research Center is a major impediment to ARS research; (4) increased support for the systematics of beneficial arthropods at the ARS Systematics Entomology Laboratory is needed; (5) there is a minimum of interaction with the private sector when establishing major thrusts in biological control; and (6) guidelines to correlate research between domestic and foreign laboratories are needed.

Status of Science and Technology -- Classical biological control of insects and mites is based primarily on studies and manipulation of arthropods. The research normally is conducted without high technology, expensive equipment, and complicated facilities. Consequently, classical biological control is often perceived as being outmoded and in need of major revisions. The recent emphasis to bring research into the laboratory and reduce the amount of field oriented studies has reduced the number and variety of projects and introductions and prolonged projects and produced data that does not reflect the actual field conditions.

The tendency to emphasize technology at the expense of the classic approach has a deleterious impact on classical biological control. A balance between innovative technology and the proven methods of biological control is essential for the advancement of this field of research.

Critical Research Needs --

(1) The ARS quarantine research capabilities nationwide must be upgraded, including establishment of a containment facility at BARC.

(2) The 75% research-25% service ratio of the European Parasite Laboratory should be changed to a 50-50 ratio. Carefully planned service functions will produce basic research.

(3) There is need for selective support for the systematics of beneficial arthropods because adequate taxonomic support is essential to the success of biological control.

(4) Interaction with industry and the private sector to determine target pests, approaches to follow, and the interrelationship of the biocontrol research with Integrated Pest Management.

(5) Need for a set of guidelines to direct foreign and domestic researchers during the development of the research plan so research at both laboratories will be compatible, comparable, and coordinated.

Biological Control of Terrestrial and Aquatic Weed and Brush Pests by Exploration, Importation and Release of Exotic Natural Enemies

L. A. Andres and T. D. Center

Weeds are an ongoing problem, causing an annual loss of $7 billion in the United States. Since 1945, approximately 50 species of bioagents have been introduced into the U.S. against 30 weed species. Control has been successful against eight of these weeds in one or more areas of their range, resulting in benefits totalling over several hundred million dollars. Based on the results of these and other efforts at biological control, an average of $30 is gained for each research dollar invested in this method of biological control.

Despite these benefits, new weed problems continue to rise. Although the concept of using natural enemies to control pests is relatively simple, and we have the ability to find and introduce new weed control agents, implementation of this approach is often complicated by scientific and logistical problems. For example, identifying weeds and then tracking their source can be difficult when plant varieties or biotypes are involved and success hinges on the availability of highly host specific, coevolved natural enemies. Increasing concern for the preservation of North American native plants closely related to the target weeds has extended the number of plant species to be included in host specificity tests and narrowed the chance of finding acceptable natural enemies. Inability to predict the behavior of candidate bioagents is proving an obstacle to their introduction against native weeds. Where mismanagement has allowed native plants to become weedy, it is questionable whether exotic bioagents alone can re-establish community balance. Difficulty in obtaining adequate numbers of newly cleared bioagents slows establishment and buildup.

Critical Research Needs -- The relative importance of the following research needs depends on the project and the opportunities at hand. If natural enemies are lacking, the search for suitable candidates assumes greater importance:

(1) Foreign exploration for natural enemies including improved methods for identifying weeds and pinpointing their origin.

(2) Studies of natural enemy-host relationships including characterization of chemical and other factors governing host specificity, and study of behavioral responses of bioagents to host and non-host plants in nature.

(3) Develop new bioagent rearing techniques, e.g. diets, diapause manipulation.

(4) Improve understanding of weed ecosystem dynamics including comparative ecological studies of weeds in adventive and native habitats, and assessing the environmental stresses acting upon the weeds and how to complement these actions.

(5) Develop models of weed buildup incorporating natural enemy impact, systems of habitat management and integration of weed control technologies.

(6) Improvement of natural bioagents to enhance adaptation to weeds, climate and problem habitat.

Biological Control of Weed and Brush Pests by Exploration, Importation, and Release of Exotic Pathogens

W. L. Bruckart

Over 60% of the weeds in the United States (U.S.) are introduced species which have proliferated to the extent that agricultural production is reduced. One advantage these species have is the lack of natural enemies where they have been introduced. Successful control of rush skeletonweed in the U.S. has resulted from introduction of *Puccinia chondrillina*, the causal agent of a rust disease. The ideal control strategy utilizes a single release of a pathogen, which becomes established and spreads without further manipulation. There are 30 species of weeds in ranges, pastures, and non-agricultural lands currently listed by the ARS as suitable for biological control, including two species of *Euphorbia*, four species of *Centaurea*, and four species of *Carduus*.

Introduction of exotic plant pathogens for biological control requires identification of pathogens in areas where the plant originated followed by evaluation of candidates in containment at the Foreign Disease-Weed Science Research Unit. Presently, the only plant pathologists involved in foreign exploration are Yugoslavian scientists associated with cooperative research that is part of a Joint Board agreement. Their research is limited to the confines of Yugoslavia.

Critical Research Needs -- The items listed are not necessarily in order of priority. Importance of a given item depends upon the stage of pathogen development for control of each target weed.

A. Overseas Exploration and Research.

1. Collect additional plant pathogens for evaluation in containment.

2. Study the impact of plant pathogens and insects on target species *in situ* (ecology).

3. Evaluate plant pathogens for virulence and specificity under field conditions (pre-screening, as with insects at BCWLE in Rome).

B. Pathogen Evaluation and Improvement.

4. Techniques to rapidly identify and describe variants of pathogens and target weeds, including improved isozyme or genetic techniques.

5. Understanding the biochemical and genetic basis for variability and specificity with regard to mechanisms of disease.

6. Improved procedures for evaluating native plants, particularly those being considered for listing as endangered or threatened.

7. Utilizing techniques for manipulation of fungi and drawing upon ideas developed in field and greenhouse studies to alter pathogens in ways that may lead to more effective weed control.

C. Ecology and Modelling.

8. Quantification of stress to weeds caused by disease, particularly identifying plant part or growth stage most seriously affected.

9. Interaction of disease with other factors that stress the target (e.g. competition, allelochemicals, temperature, moisture, etc.).

10. Interaction of agronomic practices, particularly use of pesticides, and natural enemies with regard to biocontrol of weeds.

Management of Antagonists and Competitors for Soilborne Plant Disease Control

G. C. Papavizas

It is conservatively estimated that in the U.S. alone soilborne diseases cause at least $4 billion losses on crops annually. The mission of the Biocontrol of Plant Diseases Laboratory (BPDL) is to develop biocontrol and integrated control systems against soilborne plant pathogens of major economic importance. The laboratory made the following progress during the last 3-4 years: (1) Discovered three new, unusual dematiaceous beneficial fungi on sclerotia of *Sclerotinia* in soil. One of these mycoparasites, *Sporidesmium sclerotivorum*, colonizes and destroys live sclerotia in soil (U.S. Patent No. 4,246,258). One field application of *Sporidesmium* controls *Sclerotinia* on lettuce for 3 consecutive years. The beneficial mycoparasite is now produced experimentally by private enterprise. (2) Showed that *Talaromyces flavus*, recently isolated by the BPDL, controlled Verticillium wilt of eggplant in the field and increased yield by 60-70%. The beneficial fungus, added to potato seedpieces before planting, reduced wilt and increased yield by 12-21%. *Talaromyces* is now being tested for the control of Verticillium wilt of cotton, potato, olive trees, and hops. (3) Showed that of 250 strains and 34 mutants of *Trichoderma* and *Gliocladium* tested, two strains of *G. virens* (Gl-3, Gl-21) and two strains of *T. harzianum* (Th-84, Th-87) reduced damping-off and seedling blight of bean caused by *Sclerotium rolfsii* by 50 to 90%. Also, fermentor biomass of these strains, applied to potato seedpieces as dusts, appreciably reduced in the field black scurf and stem canker caused by *Rhizoctonia solani*. Strain Gl-21 increased potato yield in Idaho by 23%. Strain Gl-21 will be developed by a major company as a biocontrol agent of Rhizoctonia and Pythium diseases on ornamental and nursery crops. The company will also pursue registration of Gl-21. (4) Developed several new stable biotypes of *Trichoderma* and *Gliocladium* by physical and chemical mutagenesis. Some of the biotypes possess superior biocontrol abilities and resistance to MBC fungicides such as benomyl (U.S. Patent No. 4,489,161). (5) The BPDL developed fermentation and delivery technology for large or small-scale distribution of biocontrol microorganisms utilizing inexpensive and readily available materials (U.S. Patent No. 4,668,512). (6) Unravelled the mechanism of action of the biocontrol fungus *Talaromyces flavus* against *Verticillium dahliae* and of the mycoparasite *Sporidesmium* against *Sclerotinia minor*. Efforts are now being made to improve the efficacy of biocontrol fungi and bacteria by recombinant DNA technology.

Management of Antagonists and Competitors for Foliar Disease Control

H. W. Spurr, Jr.

Problem Description and Importance -- Total loss to foliar diseases in the U.S. is 2 billion dollars annually. Foliar diseases cause losses amounting to 20 percent of total loss to plant disease. Foliar disease control depends primarily upon the use of resistant cultivars and pesticides. These control methods are not successful for all foliar diseases as indicated by losses. Also, these control methods are subject to increasing pressure from pathogens which can adapt.

Few practical biological control strategies have been developed which manage populations of nonpathogenic microorganisms to control populations of pathogenic microorganisms. The potential for this biological control strategy has long been recognized by plant pathologists. Research on this strategy was neglected because early attempts failed and because rapid progress in disease control was made with fungicides, resistant cultivars and management of cultural practices.

Status of Science and Technology -- Research in our laboratory parallels the development of science and technology in this area. Examples are presented in the publication: <u>Biological Control Strategies in the Phylloplane</u>, 1985, Windels, C. E. and Lindow, S. eds., APS Books, St. Paul, MN. Studies of epiphytic and endophytic bacteria and fungi in tobacco and peanut leaves began in our laboratory in 1970. These studies resulted in the development of bioassays for the selection and testing of microorganisms for biocontrol of foliar disease. The selection of bacterial antagonists for biocontrol was followed by production, formulation, application and survival monitoring of these candidates in small-scale field tests over eight years. Computer simulation models were developed to better define the characteristics required by effective antagonists and to predict efficacy based on characteristics measured in bioassays. These models were subjected to validation in field tests.

Foliar disease biocontrol has been hindered by unpredictable field results. Survival of control agents and their interactions with pathogens occur in a dynamic environment. A systems approach helps to understand these complex processes. One such approach (knowledge-based or "expert" systems) uses a set of decision-making rules (shell) coupled to a knowledge base of facts and observations. A computer simulation of Cercospora leafspot of peanut is the shell component of one such system. Disease progress is predicted as a function of weather, pathogen characteristics, plant growth, and control agents. The knowledge base contains epidemiological parameters, weather data, and results from controlled-environment studies using different biocontrol agent candidates. The model is used to optimize spray-timing and dosage, and to predict field results.

Field control has varied from 20-70% depending upon environment and resulting diseases pressure. Success is defined as controlling foliar disease at a higher level with greater consistency to compete effectively with the best fungicides. We have surpassed the poorer fungicides.

Control of Nematodes with Natural Enemies

R. L. Huettel

Problem Description and Importance -- Since 1977, most available nematicides have either been banned by the Environmental Protection Agency or are under special review because of their detection in ground water. Therefore, the development of alternate methods of plant parasitic nematode (PPN) management, such as the use of natural enemies, is of foremost importance. Even though many researchers have investigated both fungal and bacterial parasites of PPN management, no commercially available products are available in the United States. The research efforts in ARS on biocontrol of plant parasitic nematodes include only 1.3 SY's and 1.0 temporary SY. With few, if any, alternate management strategies available at this time, it is critical that nematology biocontrol research be strengthened in ARS.

Status of Science and Technology -- New research thrusts in the Nematology Laboratory at Beltsville have introduced novel approaches to biocontrol of PPN. One new area is in culturing the bacterial spore parasites of PPN. Limited success with the culturing of this organism has led to the discovery of the fact that the spore parasite is probably several species. Also, the techniques developed from the culturing have shown the commercial feasibility of mass production of the bacteria.

Another research thrust is pioneering work on specific fungal parasites of the soybean cyst nematodes. This research has been undertaken to provide new information on mechanisms of infectivity and modes of reproduction of these fungi. These approaches are aiding in development of new strategies for the use of biotechnology to enhance the fungi for better control agents of pest nematodes. Many potential management methods of PPN management, such as those mentioned above, need support so more research can be conducted to determine their actual feasibility under field conditions.

Critical Research Needs -- Nematology is in need of any support available to continue its research on natural enemies of PPN. Since the number of scientist working in this area is so

small, it is unreasonable to even attempt to propose specific research approaches. It is critical that at least one full-time SY be hired to work only on fungal parasites of nematodes. Also, funding should be made available to continue the current postdoctorate support of fungal research. The one CRIS in ARS on biocontrol of PPN management is severely underfunded and needs to be strengthened.

ARS has the opportunity to provide the farmer with alternate methods of PPN management at a time when these methods are most needed. To determine which natural enemies will succeed as control agents will take a concerted effort by researchers to understand their natural habitat, host range, efficacy and activity. This can only be accomplished by additional support from the agency.

Biological Control of Arthropod Pests of Humans and Animals

R. S. Patterson

The management of arthropod pests which affect humans and animals is not a simple process. Many different species of pests with unique biological traits are involved. This is further complicated by the fact that some of these arthropods directly attack humans and animals causing illness and death while others contaminate and destroy our food supply. Until recently, to solve this multi-billion dollar annual loss and nuisance problem, pesticides have been used extensively. Biological control was seldom if ever considered or used alone or in conjunction with other control strategies to suppress these pests. However, with the increase of pesticide resistance in many of these insects plus the possible contamination of the environment with pesticides, there is a renewed interest in potential biological control organisms. These must be meshed with the other control methods in each livestock production system or ecosystem for cockroaches, mosquitoes, and flies. Other categories of control methods to be considered are: cultural (physical and habitat alteration), chemical, and genetic manipulations. Unlike many plant pests where the immature stages are the problem, with arthropods affecting humans and animals it is usually the adults that are the pest. The immature stages are the most vulnerable and usually over 90% die off prior to adulthood by various natural limiting factors. Natural occurring biological control agents such as parasites, predators, and pathogens are major limiting factors. If the efficiency of these existing agents can be improved or added to, the indigenous pest population can be dropped to below the economic threshold level. However, great care must be taken not to upset the natural balance of the environment otherwise a situation can be created where the biological control agent becomes the nuisance or pest as has happened with many predators. We must learn the interrelationship of organisms and this can be best approached through simulated population models.

The state of the art in biological control of arthropod pests of humans and animals is still in its infancy compared to the effort in plant pests. There are probably less than 100 scientists working in this area in the entire world, most are in the U.S. and most are working on mosquito control in an augmentation capacity. In the USDA-ARS, there are only 16 scientists out of 210 total biological control specialists directly involved, with another 3-4 marginally involved such as taxonomists, genetics, etc., who work in this area. ARS devotes 11 SY's or 8% of the total biological control scientists to "Human and Animal" arthropod suppression research. This effort is roughly divided between fire ants (2.5), flies (5) and mosquitoes (2.5) and one scientists at the European Parasite Laboratory who is devoted to foreign exploration and research. This latter position has been in effect for about 3 years.

In the past two decades the scientific interest in biological control for the arthropod pests of humans and animals in ARS has mainly been confined to basic research on pathogens and predators of mosquitoes and competitors (dung beetles) and parasites of muscoid flies. Now new areas of research are being explored such as pathogens of flies, basic research into strain differences of parasitoids which attack flies, the mass releases of parasitoids for fly control, and improvement of mosquito and fly pathogens so they are more virulent. There is now a concerted effort on foreign exploration for potential biological control agents to be used for fire ant suppression. Investigations into the effectiveness of biological control agents (parasites) for the peridomestic cockroaches are also being investigated.

Augmenting Plant Pathogens as Components in Integrated Weed Management Systems

P. C. Quimby, Jr.

Problem Description and Importance -- "Current knowledge and technology are inadequate to discover, develop and use biological control agents as ecological and practical alternatives to chemical measures, or in integrated pest management programs, to control pests of crop plants. Current technology is inadequate to discover and use plant pathogens as alternative approaches for controlling many damaging weed species." An estimated 35 SY's are engaged in ARS research of all approaches for biocontrol of weeds; about 6 SY's are involved in research related to augmented weed pathogens. Methods for selective biocontrol are needed to broaden

our base of existing weed control technology. Biological control is one of several alternative approaches that may provide for safe, efficient, and selective weed control.

Status of Science and Technology -- In the augmentative approach, the pathogen is applied in a manner similar to that of chemical herbicides. This approach is effective in obtaining the rapid, high levels of weed control that are desired in agronomic crops. Technological feasibility was demonstrated by a joint effort of the U. of Florida and Abbott Laboratories with the development and marketing of Phytophthora palmivora for controlling stranglervine in Florida citrus groves. A cooperative effort among ARS, U. of Arkansas and the Upjohn Company resulted in the commercialization of Colletotrichum gloeosporioides f. sp. aeschynomene for registered use in controlling northern jointvetch in Arkansas and Louisiana fields of rice and soybeans.

Currently, a number of weed pathogens (fungi) are being evaluated. In Florida, waterhyacinth is controlled by an integrated system that includes fungus (Cercospora rodmanii), introduced insects, and herbicide application. In Georgia and Maryland, a rust (Puccinia canaliculata) is harvested from infected yellow nutsedge, stored, and is then applied and evaluated for control of that weed. A native pathogen (Alternaria cassiae) controls sicklepod. Regionwide field tests on this fungus have been conducted over the past four years among cooperating private, state, ARS, and other governmental institutions. The Mycogen Corporation, San Diego, California, has licensed the USDA patent on the organism and is attempting to develop and market it.

In Arkansas, Roy Smith, in cooperation with the U. of Arkansas, has developed technology for integrating a weed pathogen for control of northern jointvetch in rice/soybean production systems. Dr. John Cardina, in Georgia, has discovered and evaluated pathogens for control of leguminous weeds in peanuts and soybeans; he has patented, for USDA, a fungus that causes anthracnose disease of Florida beggarweed. At the Southern Regional Research Center in Louisiana, W. J. Connick and D. J. Daigle are researching biodegradable formulations of biocontrol organisms such as weed fungi and nematodes. In Maryland, W. L. Bruckart, W. M. Dowler, and J. R. Frank have investigated interactions of Puccinia canaliculata with herbicides for control of yellow nutsedge. R. H. Hodgson has cooperated with workers from McGill University, P.Q., Canada, and the U. of Vermont in research showing synergism between a plant growth regulator and Colletotrichum coccodes in control of velvetleaf. R. C. French is researching a volatile stimulator of teliospores of a rust that attacks Canada thistle. In Mississippi, C. D. Boyette conducts surveys, discovers new weed pathogens, and conducts initial characterization of these agents. He and cooperators at the U. of Arkansas are applying for a patent on Alternaria crassa for control of jimsonweed. Boyette has just discovered a promising Colletotrichum species on hemp sesbania. R. E. Hoagland is investigating biochemical mechanisms for regulation of plant resistance/ susceptibility to weed pathogens, and is researching the mode of action of phytotoxins. P. C. Quimby has discovered a new invert emulsion system for formulating weed pathogens to bypass their dew requirement, and has cooperated with Floyd Fulgham, Field Crops Mechanization Research Unit at Stoneville, on testing application of the material with a new air-assist nozzle invented by Fulgham.

Critical Research Needs --

(1) Demonstrate practical application of augmentable weed pathogens.

(2) Surveys/discovery/systematic searches for augmentable weed pathogens.

(3) Evaluation and early characterization of candidate weed pathogens.

(4) Fermentation/production of inoculum.

(5) Ecophysiological/biochemical interactions of the weed pathogens with their host plants.

(6) Formulation/application technology.

(7) Phytotoxin production and plant interactions.

Control of Insects and Mites with Pathogenic Microorganisms

C. M. Ignoffo

Problem Description and Importance -- Microbial insecticides are considered as possible safe, effective replacement for chemical insecticides. When compared to chemical insecticides, however, microbial pesticides are poorly understood, little used and insufficiently supported. To directly compete with well established chemical pesticides microbials are expected to kill immediately and be low in cost. Problems of environmental pollution, safety and resistance of chemicals, although considered by the grower, is secondary to profit. Pesticide industries with the necessary research, production and marketing resources are not interested in the limited market of biocontrol agents. This philosophy is expected to continue until a pest cannot be controlled with a conventional chemical pesticide or until regulations restrict the use of chemical pesticides for a particular crop-ecosystem. There is a good possibility that a "window of opportunity" for wider use of biological control agents will develop in the future. ARS must be ready to provide these safe, effective, biological control alternatives to chemical pesticides when that window opens.

Status of Science and Technology -- Research on microbial insecticides in ARS is mission oriented and conducted utilizing a technical-feasibility-pathway that focuses on problems from initial isolation of a candidate microbial to a demonstration of its technical usefulness and a commercial-feasibility-pathway that focuses on microbials that will or can be registered. Demonstration of technical feasibility also results in knowledge-based "products". ARS scientists have successfully used both the technical and commercial approach, and in some instances combinations of both approaches to develop biocontrol agents. One of each of the major types of pathogens (bacteria, fungi, protozoans, viruses) has been developed and registered in the USA by EPA as a microbial insecticide. Thus, commercial and experimental microbial pesticides are currently available for use in pest-ecosystems. Others, however, will have to be developed for eco-systems where we do not have safe, effective agents. Coupled with developing or isolating new, potential candidates for development into microbial pesticides is the use of classical or molecular genetics to produce novel pesticides or enhance the effectiveness of those currently registered. The ability to genetically manipulate a microorganism has rekindled the hopes of developing more effective, quicker acting microbial pesticides.

In summary, potential candidates, technology, expertise and facilities (industrial, federal, state) and regulatory guidelines are all currently available, ready and poised for the development and use of microbial insecticides. It has been established that microbials of all major groups of microorganisms can be produced, formulated, packaged, stored and marketed through current sales-distribution systems.

Critical Research Needs -- Researchable problems, associated with the more effective use of microbials, are placed into several of the following problem areas: the search, selection and development of novel candidate microorganisms by isolation as well as by classical and recombinant genetic manipulation; development or improvement of methods for characterizing and identifying biotypes; consistent availability of easily produced, effective, quality-assured preparations that can be confidently utilized in laboratory and field research; optimization and maintenance of field infectivity of natural and artificially dispersed microbials; development and optimization of application techniques and development of novel strategies to more effectively disperse and or place the candidate microbial at its most favorable infection site and; development of an overall strategy that includes the use of microbials both as insecticides and in pest management programs.

Control of Crop Insect and Mite Pests by Propagation and Release of Predators and Parasites

H. R. Gross

Summary -- Because of increasingly obvious, inherent problems associated with the use of insecticides for the management of insect and mite pests of production agriculture, propagation and release of natural enemies is being viewed with renewed promise as an effective, selective, and safe alternative management approach. Major advances in augmentation will depend primarily on the accurate prioritization of indigenous and exotic entomophages, based on their performance efficiency in the field and on their responsiveness to laboratory culture. The advancement of entomophage augmentation as a competitive and/or supporting primary management strategy will require the development of efficient, highly dependable invivo, and eventually invitro methods for mass propagating quality entomophages. Supporting technology which must be advanced concurrently includes the identification of contact host-seeking stimuli which will likely play a vital role in acceptance by entomophages of alternate hosts or synthetic diets, and the development of storage, shipment, and release methodology.

Management of Antagonists and Competitors for Postharvest Disease Control

C. L. Wilson

Postharvest diseases of fruits and vegetables are a major cause of losses in food production. Reliable loss estimates are difficult to determine. However, according to a 1956 USDA survey, postharvest losses in fruits, nuts, and vegetables amounted to about 25% of the harvested crop. Such losses are greater in export than domestic shipments and often prevent the export of certain perishables, such as peaches and papayas.

Recent incidents involving food contamination with pesticides have heightened public awareness of pesticide residues in our food. According to a 1987 U.S. National Academy of Sciences report, pesticides contaminating the most common American foods may be responsible for as many as 20,000 cancer cases a year. Such revelations have caused consumers and scientists to look more critically at pesticide contamination. Among these are the fungicides used to control postharvest rots. These developments will undoubtedly lead to a more restrictive use of pesticides on harvested food commodities. Also, resistance of microorganisms to pesticides, applied after harvest, has occurred rather frequently. The combination of all of these factors contributes to a weakening of the arsenal of weapons against the microorganism

responsible for postharvest losses. An urgent need for new and more effective means of controlling postharvest diseases is obvious.

Three factors indicate that biological control in the postharvest environment may be an exceptionally productive new area to explore. First, one of the main reasons for the failure of biocontrol procedures in the past has been our inability to control environmental conditions. Under storage conditions for harvested commodities, environmental conditions are often controlled and maintained. Second, it is often difficult to direct biocontrol agents toward effective sites. Harvested commodities do not present this problem since the areas for application are much more limited than they would be for whole plants. Third, the high value of harvested commodities may make the application of elaborate control procedures cost effective.

Critical Research Needs --

(1) Identification of effective antagonists and competitors for major postharvest disease pathogens.

(2) Understanding the mode of action of effective antagonists.

(3) Development of effective and economically acceptable production and delivery systems for antagonists and competitors.

(4) Understanding environmental effects on antagonist/pathogen/host interactions.

(5) Genetic manipulation of antagonists and competitors.

(6) Comparative economic evaluation of biological control and pesticides for postharvest diseases.

APHIS Priorities in Biological Control

G. L. Cunningham

The Animal and Plant Health Inspection Service (APHIS) was funded in 1980 for biological control implementation. Since then, the number of implementation projects has grown from two (alfalfa weevil and Mexican bean beetle) to six (alfalfa weevil, silverleaf nightshade, citrus whitefly, diffuse and spotted knapweed, Colorado potato beetle, and aphid predators). As some projects phase out, new ones such as leafy spurge, rush skeletonweed, European corn borer, and lygus bug will be phased in as resources become available.

The Agency views biological control as a high priority program and is likely to continue to do so. The success of the overall program, however, depends in large part on a strong research base and continued cooperation between APHIS and the Agricultural Research Service (ARS). This cooperation has always been mutually beneficial and provides a mechanism for practical application of basic research.

Research needs for APHIS are conveyed annually to ARS and include specific biological control and integrated pest management requests. These requests are prioritized and ranked either urgent, moderately urgent, or routine. Excerpts follow from this year's APHIS research needs package.

Urgent --

(1) Develop new biological control candidates to the point where APHIS can consider them for implementation.

(2) Develop management strategies for the *Heliothis* complex in cotton, soybean, and corn.

(3) Expand the potential of economically mass producing biological control agents and hosts through research on insect nutrition and artificial diets.

(4) Expand upon present knowledge of *Coccinella septempunctata* (C-7), *Hippodamia variegata* (HV), and *Propylea quatuordecimpunctata* (P-14) impacts on various aphid pest species in select major agricultural crops, and continue search for and development of effective biological control agents for Russian wheat aphid.

Moderately Urgent --

(1) Continue the search for and development of effective parasites for fruit flies.

(2) Develop new pathogens for grasshopper control to be used in integrated pest management schemes and which will provide high mortality in the year of treatment.

(3) Develop biological control technology for imported fire ant.

(4) Isolate, characterize, and synthesize pheromones for use in surveying for biocontrol agents released against leafy spurge, and for use in development of a bait system for controlling Colorado potato beetle.

(5) Develop synthetic media and culturing techniques for mass production of plant parasitic nematodes on Russian knapweed and silverleaf nightshade.

(6) Develop biology and life cycle data on Russian wheat aphid.

(7) Develop techniques to suppress fall armyworm in Florida, Texas, and Mexico with subsequent reduction in its migration northward through use of parasites and other pest management techniques.

(8) Evaluate effects of pathogens, predators, and hyperparasites on Lydella thompsoni under field conditions.

(9) Develop a standard with an effective method for quickly assessing Nosema locustae infections in individual grasshoppers.

Routine --

(1) Improve formulation technology and field performance of microbial pesticides used in suppression activities against the gypsy moth, especially nuclear polyhedrosis virus.

(2) Develop a rearing technique for economically mass producing Entomophaga grylli on artificial media (grasshoppers).

(3) Develop an effective method of evaluating the importance of natural occurring control agents for grasshoppers on rangeland.

(4) Conduct foreign exploration for predators, parasites, and pathogens of grasshoppers.

APPENDIX

Agenda

ARS National Biological Control Program (NBCP)
Research Priority Setting Meeting

Bioscience Conference Room, Bldg. 011A
Beltsville, MD
July 14-15, 1987

Tuesday, July 14

Moderator: E. G. King

0800 Introduction.................................. E. G. King

0815 Introductory Comments.......................... E. B. Knipling

0830 NPS Biological Control Team Comments .... Team (A. L. Christy, J. J. Menn, R. A. Bram, M. T. Ouye, H. E. Waterworth)

0900 Biological Control in Managed Ecosystems .... R. J. Cook

0930 Review of ARS Biological Control Research Activities .... E. G. King

1000 ARS Overseas Laboratories .... D. R. Kincaid

1015 BREAK

1030 Biological Control Documentation Center .... J. R. Coulson

1045 Systematics of Biological Control Agents .... L. V. Knutson

1115 Biological Control of Insect and Mite Pests by Exploration, Importation, and Release of Exotic Natural Enemies .... J. J. Drea

1145 LUNCH

1300 Biological Control of Terrestrial and Aquatic Weed and Brush Pests by Exploration, Importation, and Release of Exotic Insects, Mites, and Nematodes .... L. A. Andres, T. D. Center

1330 Biological Control of Weed and Brush Pests by Exploration, Importation, and Release of Exotic Pathogens .... W. L. Bruckart

1400 Management of Antagonists and Competitors for Soil-borne Plant Disease Control .... G. C. Papavizas

1430 Management of Antagonists and Competitors for Foliar Disease Control .... H. W. Spurr

1500 BREAK

1530 Control of Nematodes with Natural Enemies ...... R. L. Huettel

1600 Control of Insect, Mite, and Tick Pests of Man and Other Animals with Natural Enemies .... R. S. Patterson

1630 Control of Stored-Product Insects and Fruit Flies with Natural Enemies .... T. T. Y. Wong

1700	DINNER	
2000	Augmenting Plant Pathogens as Components in Integrated Weed Management Systems	P. C. Quimby
2030	Augmenting Insect and Mite Pathogens as Components in Integrated Pest Management	C. M. Ignoffo, R. S. Soper
2100	Control of Crop Insect and Mite Pests by Propagation and Release of Predators and Parasites	H. R. Gross
2130	Management of Antagonists and Competitors for Post Harvest Disease Control	C. L. Wilson
2200	ADJOURN	

Wednesday, July 15

0815	Biological Control Priority Setting in OICD, IRD	R. C. Hedlund
0830	APHIS Priorities in Biological Control	G. L. Cunningham
0900	Identify and Prioritize Critical Research Needs	
	Biological Agents for Insect and Mite Control ...	E. G. King/Group
	Biological Agents for Weed and Brush Pest Control	A. L. Christy/Group
	Biological Agents for Plant Pathogen and Nematode Pest Control	H. E. Waterworth/ Group
1200	LUNCH	
1300	Group Reports and Comments (Moderator: E. G. King)	
	Biological Agents for Insect and Mite Control	E. G. King
1345	Biological Agents for Weed and Brush Pest Control	A. L. Christy
1430	Biological Agents for Plant Pathogen and Nematode Pest Control	H. E. Waterworth
1515	BREAK	
1530	Future Plans	
1600	ADJOURN	

Biological control concepts and approaches: A synopsis of the 1987 briefing report on biological control in managed ecosystems

R. J. Cook

In late 1986, the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academy of Science and the National Academy of Engineering requested a briefing report for 1987 on "Biological Control in Managed Ecosystems." Besides the written report[1/], four oral briefings were presented in Washington in May/June 1987, including to: 1) interested representatives of federal agencies and scientific societies; 2) Assistant Secretary of Agriculture, Orville Bentley, and representatives of agencies within Science and Education of the USDA; 3) Eric Bloch and his staff of the NSF; and 4) William Graham and his immediate staff in OSTP. These briefings represented a unique opportunity to make the case for research and development related to biological control of plant pests.

The 12 panelists who produced this report included six who work mainly at the molecular and cellular levels in biological control and six who work mainly at the organismal and ecosystem levels. Four panelists represented industry, three were from federal agencies (ARS and NIH), and five were from Land-Grant universities. Four panelists work on insect control, one on nematodes, three on plant diseases, and four were specialists in aspects of microbiology, ecology, and plant molecular biology.

The Briefing Report states, in essence, that biological control can and should become the primary method of pest control used in the United States to insure the health and productivity of plants and animals important to us. The report does not state that biological control should be the only method of pest control, but rather, that it should be the method sought first to control pests and that chemicals should be used as the last choice and only to the extent that biological control is not successful. The report states further that this approach to pest control is necessary to improve or at least protect the quality of our environment, the sustainability of our agriculture, and U.S. competitiveness in world markets, but is slow to develop because of inadequate basic information, too little interdisciplinary effort needed to solve complex problems, and constraints on getting research from the laboratory to the field.

Biological control is broadly defined in the report to include "the use of natural or modified organisms, genes, or gene products to reduce the effects of undesirable organisms (pests), and to favor desirable organisms such as crops, trees, animals, and beneficial insects and microorganisms." Managed ecosystems are defined as "environments managed for human benefit." They include farmland, rangeland, forests, lakes, and urban and residential areas. Biological control in managed ecosystems "includes the manipulation and strategic introduction of organisms, genes, or gene products to influence the outcome of otherwise natural biological interactions in a manner favorable to humans."

The broad definition, i.e. one that includes pest control by introduction of genes or gene products and not just whole organisms as biological control, was used for several reasons. Three major reasons are given below.

1. It is scientifically indefensible to narrow the concept of biological control so that introduction or manipulation of organisms for pest control purposes qualifies as "biological control" but introduction or manipulation of genes for pest control purposes does not qualify as biological control. These areas of biology are parts of a continuum. Research is needed on ways to manage the outcome of biological interactions at all levels--the molecular, cellular, organismal, and ecosystem levels. Some pests may be controlled by introducing an organism, others by introducing one or a few genes from that or some other organism. Both are examples of biological control.

2. A broad definition is more futuristic in view of the new biotechnologies that have already begun to blur boundaries of what were once considered to be very different areas of research. For example, the bt gene for production of endotoxin in *Bacillus thuringiensis* has now been transferred to and expressed in a strain of *Pseudomonas fluorescens* adapted to the rhizosphere of corn, and it has also been transferred to and expressed in leaf cells of tobacco. Our concept of biological control should not be so narrow that expression of the bt gene in a microorganism such as *B. thuringiensis* or *P. fluorescens* is biological control, but its expression, a mechanism of host-plant resistance, is not biological control.

3. The broad definition has a psychological effect of bringing more disciplines together to help solve the complex problems required to control pests without the use of chemical (synthetic) pesticides. Those working to control pests by genetic improvement of plants are in the biological control business just as much as those working to control pests by introduction of natural enemies or antagonists of plant pests. Both approaches have succeeded in the pest by use of biological material obtained from the original "home" of the pest, i.e., genes for resistance to the pest or natural enemies of the pest. Both approaches have the ultimate effect of controlling pests without the use of hard pesticides and both should and can be integrated.

[1/] Research Briefings 1987: Report of the Research Briefing Panel on Biological Control in Managed Ecosystems, National Academy Press, Washington, 1987, 12 pp.

On the other hand, this definition is not so broad as to include every approach to pest control other than use of hard pesticides. Practices such as tillage for weed control, open field burning for pest control, and heat therapy or meristem culture to eradicate viruses in planting material are examples of "physical control."

In an agency such as ARS, it would seem advantageous if not essential to categorize the agency's total effort in pest control into no more than three or four areas, e.g. biological control, physical control, chemical control, and IPM. Three of these have the ultimate effect of reducing the dependency of our managed ecosystems on hard pesticides for pest control.

The briefing report identifies three basic biological control strategies.

1. Regulation of the pest population: biological control agents to regulate the pest population at or below an acceptable threshold, e.g., the *bt* gene expressed in *B. thuringiensis*;

2. Exclusionary systems of protection: beneficial microorganisms as a living barrier that excludes infection or deters pest attack, e.g., the *bt* gene expressed in *P. fluorescens* in the rhizosphere of corn; and

3. Self defense: resistance mechanisms in the plant or animal host to prevent or suppress disease or pest damage, e.g., the *bt* gene expressed in leaf cells of tobacco.

These three basic biological control strategies are a logical progression from (1) reducing pest numbers within the ecosystem to (2) keeping the pest from contacting or entering the host plant or animal to (3) limiting effects of the pest after infection or attack. Biological control of weeds will be considered effective mainly or only if the number of weeds in the ecosystem is reduced. With many plant pathogens, on the other hand, size of the population may not be critical so long as infection is prevented or disease development is suppressed. Many plant pathogens, e.g., viruses and certain prokaryotes, complete their entire life cycle inside the plant and the approach to their biological control must seek to attenuate or prevent the process of pathogenesis. The pathogen population may then decline but this is secondary to keeping the plant healthy. Small pox has been controlled globally by strategy 3, a system of self-defense in humans initiated by inoculation of humans with an attenuated strain of the small pox agent; the amount of small pox inoculum presumably has declined as a consequence of the control, with the result that inoculation of humans is no longer essential, but this presumed decline in the amount of inoculum was not necessary to control the disease.

The populations of soilborne pathogens responsible for root diseases have traditionally been lowered to safe levels by crop rotation, i.e. by allowing time between host crop plants for the natural enemies to reduce their numbers. These populations have also been lowered by use of tillage, which accelerates and intensifies the biological destruction/displacement of pathogens in soil and crop residue. Both techniques fit into strategy 1. With the trend toward shorter or no crop rotation and reduced or no tillage, root disease control in the future may depend increasingly on strategy 2 (biological protection against infection) and strategy 3 (restriction of disease progress after infection).

Each of these three strategies may be approached using (1) the pest agent against itself, (2) natural enemies or antagonists of the pest agent, or (3) the host plant or animal that benefits. Charts 1 and 2 are developed from the Briefing Report and give examples of how each of these three components has been or might be used in a given strategy. The matrix in chart 1 includes mainly examples that are already working or have been field tested. The matrix in chart 2 includes mainly examples involving the new biotechnology.

Pest control can be achieved by cultural practices that conserve or even enhance (maximize) the indigenous (background or constitutive) biological control. As a second method, exotic enemies of naturalized pests or genes for resistance to the pest can be introduced as deliberate introductions/releases. Both of these methods depend on knowledge of the ecology of the pest agent and of the mechanisms of biological control. Both methods also depend on public-supported research and technology transfer. A third method involves repeated introductions of the biocontrol agent. Such agents include the "microbial pesticides" and are the most marketable biological controls. Chart 3 illustrates these three methods. The tools of molecular biology have the potential to contribute to all three methods: better microbial pesticides; new genes or improved biocontrol agents; or better understanding of mechanisms essential to designing the best cultural practices.

Biological control documentation center, Agricultural Research Service

J. R. Coulson

Introduction: The U.S. Department of Agriculture has been engaged in the introduction and release of exotic natural enemies since the inception of Biological Control in this country in the 1880's by C. V. Riley, then Chief Entomologist for the Department. It was under

Methods of Biological Control

Occasional Introduction of Organism or Gene -- "Self-Maintaining"

Background (Constitutive) Biological Control -- Maximized by Cultural Practices

Repeated Introductions -- Microbial Pesticides

Chart 1.

Biological Controls

	Regulate The Pest Population	Exclusionary Defense System	Self Defense
Pest Used Against Itself	Genetically Modified Vector	ice-minus *P. syringae*	TMV Coat Protein Gene
Natural Enemies; Antagonists	*Bt* in *B. thuringiensis*	*Bt* in *P. flourescens*	*Bt* in Tobacco
Plant or Animal That Benefits	Trap Plants	Modified Growth Habit	Genitically Engineered for Resistance

Chart 2.

Biological Controls

	Regulate The Pest Population	Exclusionary Defense System	Self Defense
Pest Used Against Itself	Sterile Males	*Agrobacterium* K84	X-Protection
Natural Enemies; Antagonists	Parasitoids	*Lactobacillus* in Piglets	Induced-R
Plant or Animal That Benefits	Cultivar Mixtures	Dense Sowing of Cereals	Host Plant Resistance

Chart 3.

Riley's leadership that the highly successful biological control of cottonycushion scale on citrus in California was accomplished by the introduction of the predatory Vedalia beetle from Australia, 1888-89. This outstanding success accelerated the development of "classical" biological control in this and other countries.

Background History: During the early years of this century, the U.S. Department of Agriculture (USDA), together with the University of California and Hawaiian Department of Agriculture, increased their foreign explorations for promising natural enemies to introduce for the control of insect pests in the United States. Major target pests for USDA explorations included the gypsy moth, European corn borer, Oriental fruit moth, and Japanese beetle. These explorations resulted in the opening of overseas biological control laboratories by the USDA in France, Hungary, and Japan, to study and collect natural enemies of insect pests in those areas that had been accidentally established in the United States.

In 1934, administrative responsibility for all USDA biological control foreign exploration activities was centralized in the Foreign Parasite Introduction Division of the Bureau of Entomology and Plant Quarantine. This Division and its successor organizations were responsible for the administration and direction of foreign exploration activities until 1972. And, in the 1940s, domestic quarantine facilities designed to safely receive, clear, and distribute imported natural enemies were established in New Jersey and placed under the administration of the Division. Also in the 1940s, the study and importation of exotic weed-feeding insects was begun in California, which activities were also placed under Division responsibility. Overseas laboratories for the study of natural enemies of introduced weeds were established in Italy (1959) and Argentina (1962). Additional quarantine facilities and other domestic locations for research on, and the release, establishment and distribution of imported natural enemies of insect and weed pests in the United States were added to the foreign exploration activities in the 1950s and 1960s under the direction of the Insect Identification and Parasite Introduction Research Branch of the Entomology Research Division of the Agricultural Research Service (ARS).

Establishment of the Documentation Center: In 1972, administration of the natural enemy introduction programs by the Branch ended, and the files of the old Division and disbanded Research Branch were placed in what is now the Beneficial Insects Laboratory (BIL) of the Plant Sciences Institute at Beltsville, Maryland. The valuable and voluminous BIL files contain unpublished reports and records, correspondence, and literature on USDA and various State natural enemy introduction programs dating back to at least 1934. These unique files are one of the important sources for the computerized databanks of biological control information being developed in BIL.

In 1978, a special study team coordinated by USDA's Office of Environmental Quality published a detailed report strongly recommending the development of "a national information storage and coordinating system specifically designed for assembling and collating domestic and international information relevant to all biological agents that might be used for pest control." This was one of a series of high priority recommendations by the study team intended to strengthen research on the use of biological agents for pest control and in IPM programs, and led to the establishment of the Documentation Center. In October 1982, the ARS formally established the ARS Biological Control Documentation Center in BIL.

Objectives: The overall goal of the Center's computerized documentation program is to develop information-delivery and documentation systems to provide biological and taxonomic data on arthropod, weed, and other pests and on their endemic, introduced and foreign natural enemies. Emphasis is on data of use in making effective research and management decisions for biological control programs particularly in natural enemy introduction programs.

Procedures and Activities: Biological shipment record forms designed by the Center provide for the first time a standardized procedure for documenting diverse information about the introduction and movement of natural enemies for pest control in the U.S. Details on the importation and release of exotic biological control agents and pollinators are being computerized by the Center and will be published on an annual basis. The first, for 1981 releases, will be published in 1988. Such an annual "release bulletin" has been published on Canadian biological control releases for many years, but has not heretofore been possible in the U.S. This documentation program, entitled "Releases of Beneficial Organisms" (ROBO), will be backed up by specimens representing releases in the U.S. in the "U.S. National Voucher Collection of Beneficial Arthropods."

Another documentation activity of the Center involves the production of a periodic Biological Control Information Document, which includes rosters of USDA and Canadian biological control workers and information of interest to them, such as procedures for obtaining assistance and live material from ARS and other overseas biological control laboratories and identification of arthropods from ARS Systematic Entomology Laboratory. Several other databases, including "Pest Organisms and Their Natural Enemies in the U.S." (POUSNE), which will include data on all U.S. pests (arthropods, weeds, nematodes, and plant pathogens), are among the plans of the Documentation Center after the ROBO program becomes fully operational. The "Western Hemisphere Immigrant

Arthropod Database" (WHIAD) contains detailed information on all arthropods, both pests and natural enemies, that have been accidentally or purposefully introduced into North America. ROBO, POUSNE and WHIAD will be highly interactive databases of great importance to Federal and State biological control and taxonomic research workers and administrators, and to agricultural and biological research in general.

ARS National Biological Control Program (NBCP) Review of ARS Biological Control Research Activities

E. G. King

The book "Research Planning Conference on Biological Control, March 20-22, 1984," overviews the field of biological control. Objectives for a range of research areas and recommended research approaches for ARS are given in this document. Pests are ranked by commodity or area using selected criteria.

Nevertheless, I have gotten the impression that, in general, this document is seldom used and has had little effect on the direction and tempo of biological control research in ARS. This is unfortunate because this document represents the input of numerous scientists and administrators, months of work, and hundreds of thousands of dollars.

It is my opinion that this document, coupled with the BARC Symposium, "Biological Control in Crop Production" and the USDA report "Biological Agents for Pest Control: Status and Prospects" as well as a few other documents, provide direction for research on ARS biological control. In my opinion, a weakness of the 1984 ARS effort was failure to clearly delineate the ARS resource base on biological control, a definitive program with focus was not developed, i.e., the objectives and research approaches were too diffuse, and there was not enough NPS and administrative follow-through on the conference report.

It is obvious from Dr. Knipling's remarks that the time is now right for developing a unified ARS National Biological Control Program. You received, last week, profiles on all the scientists researching biological control in ARS. These scientists with their Work Units, facilities, and equipment, constitute the ARS resource base on biological control.

You are all experts in your respective areas, and I am sure that you are familiar with the documents that I mentioned. So, I believe that after you listen to today's presentations you will be in a position to at least provide us with a tentative ranking of the highest priority critical research needs for progress in biologically controlling pests. This will lend focus to the NBCP.

Moreover, I hope you will agree to continue to work within the framework of this program to provide the necessary follow-through in conducting critical path analyses (CPA) to determine the research events which we must satisfy in obtaining our goal. Conduct of CPA's will pinpoint the bottlenecks that must be removed to satisfy the critical research needs. Knowledge of the resource base will allow us to refocus and redirect resources around bottlenecks or impasses in the path toward our goal.

You, as a Core Group, will provide the necessary follow-through and serve as a reservoir of information and support for the NBCP. Obviously, presence of a NPL having direct responsibility to the program, and who can chair our group will be important in providing the leadership and follow-through that heretofore have been missing, particularly in Entomology[1/].

Pressures to develop approaches for controlling pests as alternatives to pesticides continue to increase. Apparently, public concern over environmental safety is driving the interest in reducing the amount of pesticides used. This interest is reflected in concern over groundwater quality and the occurrence of pesticides on food. The Endangered Species Act reflects the public's concern over effects of pesticides on wildlife and other nontarget organisms including people. Modifications of the Delaney Clause reflect the public's concern over pesticide residues in their food, and the safety of this food. Farmers are concerned about staying in business, so they are interested in increasing production efficiency to improve profitability. Consequently, expanded use of biological control agents in lieu of pesticides is in the best interest of the farmer as well as the environmentalist. Use of naturally occurring or augmented biological control agents is often less expensive than using a pesticide; biological control agents may be a renewable resource as opposed to petroleum-based pesticides; and biological control agents do not contaminate the environment. Finally, pesticides are often rendered ineffective due to selection of resistant pest populations, and biological control agents serve as an alternative control procedure.

As Jim Cook described, there are many forms of biological control. In delineating the NBCP, I chose a more conventional and restrictive definition for biological control. This working definition is: "Management of natural enemies (predators, parasites, and pathogens of pests) and selected beneficial organisms (certain antagonists and allelopaths) and their products

1/ Biocontrol Working Groups are being formed as an advisory component of the ARS National Biocontrol Program. Each group consists of specialists providing analysis, data, and advice about biocontrol within a specific area of research, e.g., "Augmentation, Classical, and Conservation Biocontrol working Group" and "Microbial Biocontrol Working Group."

to reduce pest populations and their effects." This definition does not include cultural control or forms of biological control such as genetic or autocidal host plant resistance; nor does it include physical or chemical means of control except as these approaches affect the biological control agent. These control approaches, along with biological control, are vital components of integrated pest management (IPM).

The 218 biological control scientist profiles you received last week were developed from questionnaires distributed to you and other ARS scientists in April. There were 360 questionnaires distributed, and each questionnaire consisted of 9 parts: (1) Laboratory or Research Unit Name; (2) Location Address; (3) Business Phone Number; (4) CRIS Work Unit(s); (5) Control Approach(es); (6) Research Area(s); (7) Protected Commodity(ies); (8) Biological Control Agents Researched; and (9) Current Area of Research Activity.

We were highly pleased with the response and interest of the scientists, Area Director, and National Program Staff to our questionnaire. However, the profiles were completed only after numerous phone calls, particularly by Jack Coulson, to clarify the responses. The data base for the NBCP is now in its fourth comprehensive revision and I expect that this will be a continual updating process in the future because of the dynamic nature of research priorities, scientists, CWU's and the magnitude of the Program. The Program has been established on D-Base III Plus software. Perhaps maintenance of this data base can become a function of the ARS Biological Control Documentation Center.

In our first attempt to delineate the NBCP resource base, we determined that it was distributed across 3 of the 6 Objectives in the ARS Strategic Plan, and 12 elements and 14 problems. Thirty subproblems contained biological control diction. We knew that the NBCP could not be delineated by simply reading the subproblem definitions in the Strategic Plan nor could scientists be identified and their SY and dollars be quantified by simply reading their CWU including their title page, 416, 417, and most recent 421. So, this was the reason that the questionnaire was developed. Names of the scientists polled were pulled from a wide range of sources.

Based on our survey the ARS-NBCP is now distributed across the Strategic Plan in 5 Objectives, 10 Approach Elements, 25 Elements, 29 Problems, and 82 Subproblems. This research effort is housed in 73 units or laboratories, in 31 states, and France, Italy, Argentina, and South Korea, and it is conducted by 218 scientists constituting 143.5 SY's in 176 CWU's. The dollar figures we derived from the questionnaire and telephone survey were $18,633,839 or $129,853/SY, but these figures are in immediate need of revision. In fact, the actual figure is probably closer to $20 million or $139,373/SY.

The ARS-NBCP is primarily distributed across 3 objectives in the Strategic Plan: Objective 2 - Plant Productivity (103 SY); Objective 3 - Animal Productivity (10.1 SY); and Objective 4 - Commodity Conversion and Delivery (8.7 SY). Of these SY, over one-third (53.1) are in Element 2.4.09, which is the designated biological control element in Objective 2. Other important elements are 2.2.01 (genetic engineering) and 2.2.05 (genetic improvement) for a total of 8.4 SY. Biological control of plant pathogens and nematodes is largely contained in elements 2.4.02 and 2.4.03 (total = 13.2 SY). Biological control of weed and brush pests is given in elements 2.4.06 and 2.4.07 (total = 10.1 SY). Biological control of human and animal pests is in Approach Element 3.5 (10.1 SY), and biological control of post-harvest pests is largely in Approach Element 4.3 (8.7 SY). Element 2.1.02 contains the ARS effort on systematics of natural enemies, particularly of arthropods. It consists of 12 SY.

Obviously, there is an opportunity to consolidate ARS biological control research under fewer elements, problems, and subproblems, but this is of secondary importance now that the CWU's, scientists, SY's, and dollars have been identified. Biological control can be coded into the CWU as, at least, a subactivity even if the SPC is not explicit on the biological control content.

The biological control approach containing the greatest scientific effort is Augmentation, i.e., the propagation and release or application of biological control agents with 148 scientists constituting 77.2 SY. Classical biological control, i.e., the exploration, importation, release and evaluation of exotic biological control agents for establishment is researched by 84 scientists constituting 43.4 SY. The remaining SY's are researching environmental manipulations to preserve and increase the effectiveness of naturally occurring biological control agents (biological control by conservation of natural enemies) (Fig. 1).

The research efforts on biological agents for control of arthropods and on arthropods controlling weed and brush pests predominate in the NBCP with 110 out of 148 SY (Fig. 2). Insofar as research areas are concerned, most scientists are involved in release and evaluation, developmental biology, and population processes, followed by systematics (Table 1). Over half (74 SY) of ARS scientists researching biological control are involved in protecting plants from insects and mites. Only 8 SY are dedicated to protecting post-harvest products from insects and mites and 12 SY are dedicated to protecting humans and other animals from insects, mites, and ticks. Forty scientists constituting 25 SY research biological control of weeds, including use of phytophagous arthropods and microbes. Research on use of nematodes to control weeds and on biological control of nematode pests consisted of only 2 SY. (See Tables 1-3 in Minutes of the Research Priority Setting Meeting, pages 4-6).

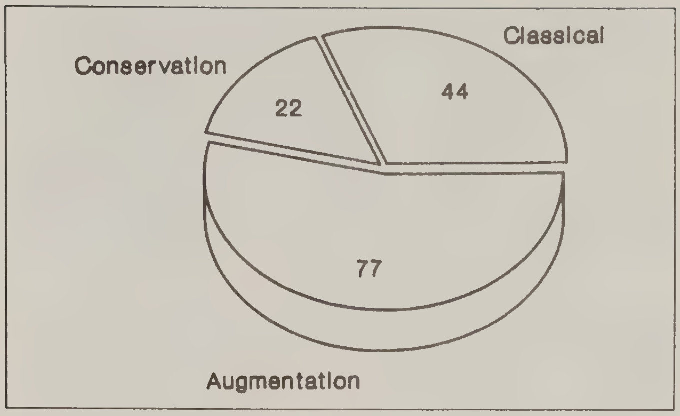

Figure 1.
Research effort (scientific years) with ARS/NBCP by biological control approach.

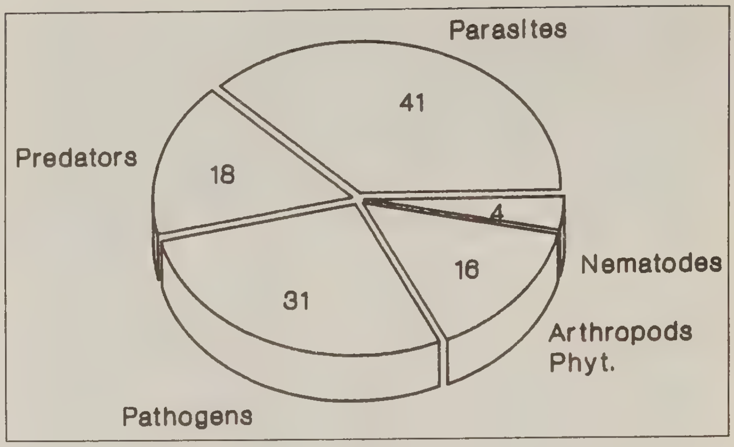

Figure 2.
Research effort (scientific years) on biological control agents of arthropod pests and on use of arthropods for controlling weed and brush pests.

Table 1.
ARS national biological control program

Research Area	Biological Control Agent (SYs)a/						
	Arthropod			Microbial	Plant	Phytophagous	
	Parasites	Predators	Pathogens	Antagonists	Allelopaths	Arthropods	Mycoherbicides
Systematics	5.9	3.5	2.3	2.0	0.0	0.7	0.1
Foreign Exploration	2.9	1.3	0.7	0.1	0.0	1.9	0.3
Quarantine/Clearance	0.9	0.6	0.2	0.0	0.0	4.5	0.8
Release/Evaluation	6.4	2.2	2.3	1.2	0.1	4.0	0.6
Development Biology	6.4	2.1	6.7	6.5	0.0	2.2	1.3
Population Processes	7.8	3.0	3.9	3.7	0.2	1.1	0.1
Modeling/Systems Anal.	1.6	0.8	1.2	0.5	0.0	0.2	0.0
Semiochemicals	2.4	0.8	0.0	0.0	0.0	0.0	0.0
Pesticide/BC Agent	1.3	0.8	1.0	0.2	0.2	0.3	2.0
Propagation	2.5	1.7	3.9	0.6	0.0	0.7	0.3
Genetic Improvement	1.6	0.4	4.0	3.7	0.0	0.0	0.0
Application Systems	1.5	0.4	2.0	2.0	0.0	0.1	2.6
Economic Analyses	0.1	0.0	0.0	0.2	0.0	0.1	0.0
Allelopathy	0.0	0.0	0.0	0.0	2.1	0.0	0.0
TOTAL SYs	41.2	17.5	31.5	21.6	2.5	15.8	8.3
TOTAL Scientistsb/	88	58	55	35	9	21	13

a/ SYs derived by formula, Biological Control Agent SYn * Research Area SYn/Total Research Area SY.
b/ Total scientists exceed 218 because some scientists conduct research across research areas and biological control agents.

Table 1. Continued.

	Biological Control Agent (SYs)					
Research Area	Phytophagous Nematodes	Entomogenous Nematodes	Herbivorus Fish	Nematophages	SY	Scientists
Systematics	0.0	0.1	0.0	0.3	14.9	36
Foreign Exploration	0.0	0.1	0.0	0.0	7.3	31
Quarantine/Clearance	0.0	0.0	0.0	0.0	6.9	24
Release/Evaluation	0.0	1.0	0.1	0.0	17.9	64
Development Biology	0.0	0.8	0.0	0.6	26.5	101
Population Processes	0.0	1.0	0.0	0.0	20.8	82
Modeling/Systems Anal.	0.0	0.2	0.0	0.0	4.4	24
Semiochemicals	0.0	0.0	0.0	0.0	3.2	14
Pesticide/BC Agent	0.0	0.0	0.1	0.0	5.7	34
Propagation	0.0	0.3	0.0	0.0	10.0	42
Genetic Improvement	0.0	0.1	0.0	0.0	9.7	25
Application Systems	0.0	0.5	0.0	0.1	9.0	46
Economic Analyses	0.0	0.1	0.0	0.0	0.5	3
Allelopathy	0.0	0.0	0.0	0.0	2.1	7
Total SY	0.0	4.1	0.2	1.0	143.5	
Total Scientists	1.0	10.0	1.0	1.0		
	1.0	10.0	1.0	1.0		

Research Needs

A. Project Selection

Establish rational methodology for selecting biological control agents, pests, and ecosystems to ensure success of biological control.

See also Operational Needs #2 and 9.

B. Classical Biological Control Approach (see also E)

Continue to emphasize foreign exploration and introduction of biological control agents with participation of lead scientists to be involved in foreign exploration.

Increase short-term participation of domestic researchers at overseas laboratories.

Comprehensive ecological studies in conjunction with foreign exploration.

See also Operational Needs #2, 3, and 6.

C. Large-scale Rearing of Biological Control Agents

Sex ratio problem, especially of arrhenotokous species.

Develop methodology for production of high quality biological control agents in numbers adequate for field testing in plots of manageable size.

Develop mass propagation and large-scale rearing technology including _in vitro_ and _in vivo_ rearing procedures for biological control agents.

Quality control in mass rearing.

Consistent availability of effective, quality-assured biological control agents.

Develop and refine methods for storage, shipment and release of biological control agents.

D. Genetic Improvement

Strain difference recognition and strain improvement.

Isolation, selection for, or genetic manipulation of novel, effective candidate biological control agents.

Development of methods for characterizing and identifying biotypes of biological control agents.

Genetically improve biological control agents with emphasis on developing pesticide resistant biotypes for establishment and augmentation.

E. Containment Research

Establish a multi-purpose research/containment facility.

Increase quarantine facility capabilities (USDA-owned) on west coast to handle biological control agents of weeds, insects and pathogens.

Multi-purpose research quarantine facility at BARC.

Develop capabilities for containment research and subsequent field research on a regional basis (especially multi-purpose at BARC) for receipt and study of exotic, biotic agents of various taxa.

Develop facilities and procedures for study of exotic, entomogenous nematodes.

F. Basic Research on Biocontrol Agents

Host and parasitoid demographic studies.

Interrelationship of the various species from both native and introduced habitats.

Intra- and interspecific competition studies.

Behavior studies -- dispersal, searching ability, defense mechanisms, etc. (basic biology).

Laboratory studies, reproductive potentials and developmental rates.

G. Integrated Pest Management

Determine opportunities for conservation approaches.

Develop principles of arthropod epizootiology as a basis for use strategies in pest control.

IPM with biocontrol component to include new formulations of existing chemicals so they are non-injurious to biological control agents (chemical selectivity, formulation and application systems).

Determine the ways of integrating pathogens for pest control with other crop protection technology into production systems.

Select pesticides that are selective for the pest but allow biological control agent survival.

Development of an overall strategy that includes the use of biological control agents in pest management programs.

See also Operational Need # 7.

H. Augmentation Approach (See also C)

Delineate area of movement/dispersal for the entomophage and pest for areawide suppression.

Develop capabilities for assessing impact of biological control agents of seasonal F1 generations of the host.

Maintenance and optimization of effectiveness of artificially applied or naturally dispersed and indigenous biological control agents.

Develop release systems and determine release rates.

Identify source(s) of contact, host-seeking stimuli for use in retaining selected entomophagous species in a targeted area.

Optimization of current, and development of novel techniques for dispersion and selective placement of biological control agents.

Conduct experiments to assess the feasibility of augmenting selected biological control agent populations to suppress the pest, increase yield and minimize pesticide usage.

See also Operational Needs # 4, 6, 8, and 10.

I. Taxonomic Research

Determine capability gaps in systematics support for biocontrol to obtain increased support for this service.

Plant-feeding mite systematics capability.

Lepidoptera systematics capability (especially larvae).

Improve the taxonomic capabilities for biological control agents.

Database of pests in the U.S. and their natural enemies.

Increase support for taxonomic research on natural enemies and their hosts of importance to biocontrol.

Pest-host, larva-adult associations and indentification of larvae of fruit flies.

Establish inventories of biological control agents for important exotic pests and ranking according to selected criteria as to likelihood for establishment in the U.S.

Develop both biotechnological and dry-bones methods for biosystematics.

Maintain biosystematic services for Latin America.

Spider and tick systematic capabilities.

J. Economic Research

Develop cost-benefit analysis for each successful project.

See also Operational Need # 5.

K. Computer Technology

Develop computer-based decision-making technology that makes explicit use of biological control agent populations in treatment/no treatment decision-making.

The development of simulated computer models for the prediction of the success of incorporation of biological control agents in IPM programs.

See also Operational Need # 1.

L. User Groups

Develop joint research efforts with industry to determine best utilization of potential biocontrol products.

Operational Needs

1. Assure continuance of ARS National Biological Control Documentation Center leadership (understudy position plus support).

2. Develop improved procedures for establishing, implementing, coordinating and evaluating overseas biocontrol research/service projects.

3. Establish guidelines for joint domestic and foreign biocontrol to ensure comparable results.

4. Establish and integrate a repository for arthropod pathogens into the national germplasm system.

5. Devise better publicity for biocontrol.

6. Establish procedures for ARS biocontrol programs to meet requirements under the National Environmental Policy Act and the Endangered Species Act.

7. Sufficient staff, facilities and time to run a comprehensive program.

8. Develop procedures to work with APHIS to advance a national bioagent dispersal program and large-scale field demonstration plots.

9. Establish network for supplying information to APHIS regarding priority setting for advancing biocontrol programs.

10. Transfer developed augmentation technology to APHIS and/or interested industry.

Profiles of ARS Biological Control Scientists

This section represents the results of the survey conducted in May 1987 by E. G. King and J. R. Coulson, as noted in the minutes of the Research Priority Setting Meeting, p. 4, and in Dr. King's presentation, Paper 3, Appendix, p. 26.

Changes have occurred since completion of this survey and development of these Profiles, including (1) changes in the CRIS numbering system, (2) termination, replacement, or other changes to CRIS projects, (3) movement or retirement of scientists, and (4) organizational changes. No effort has been made to note organizational changes that have occurred since May 1988. These will be reflected in the next revision of the Biological Control Information Document in preparation by the ARS Biological Control Documentation Center.

Information used to generate these Profiles are stored in a database management system (dBASE III PLUS software) at Beltsville, MD and Stoneville, MS. A variety of data management tasks are possible, i.e., editing, field searches, data retrieval, and formatted output. It has not been structured as a menu-driven database system, however, retrieving and collating biocontrol information is possible relative to protected commodities, research activities, scientists, laboratories, and strategic plan codes, as well as other data fields.

Profiles of ARS Scientists Researching Biological Control of Insect, Mite, and Tick Pests

Adams, J.R. Insect Pathology Laboratory USDA-ARS, Rm. 207 Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-4332 FTS: 344-4332	Develops new knowledge and improved control principles for using insect pathogens as microbial control agents. Specifically isolates, purifies, and identifies newly discovered insect pathogens and studies the histopathogenesis of them using electron microscopy. Characterizes pathogens in insect mass rearing epizootics and develops control measures.
Anderson, D.M. Systematic Entomology Laboratory c/o National Museum Natural History Washington, DC 20560 Phone: 202-382-1794 FTS: 382-1794	Develops, synthesizes, and disseminates information on larvae of lady beetles and some weevil pests and of the weevil genus _Smicronyx_ (adults). Some lady beetles and a few _Smicronyx_ species are of significance as active or potential biocontrol agents.
Ashley, T.R. Insect Attractants, Behavior, and Basic Biology Research Laboratory P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5761 FTS: 947-7761	Population dynamics and modeling of crop insects and their parasites, with special emphasis on _Spodoptera_.
Banks, W.A. Insects Affecting Man and Animals Research Laboratory 1600 SW 23rd Dr., Box 14565 Gainesville, FL 32604 Phone: 904-374-5780 FTS: 947-7780	Conducts foreign exploration to discover parasites, predators, or pathogens of fire ants. Evaluates effects of organisms on fire ants in native habitat. Emphasis is on management of _Solenopsis_.
Beegle, C.C. Insect Pathology Laboratory Rm. 303, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-2645 FTS: 344-2645	Investigate pathological interactions of _Bacillus thuringiensis_ and coleopterous pest larvae, and explore possibilities for use of _B.t._ toxins in the control of same.

Biever, K.D. Yakima Agricultural Research Laboratory 3706 West Nob Hill Blvd. Yakima, WA 98902 Phone: 509-575-5963 FTS: 446-5693	Develops fundamental principles and new knowledge to facilitate the integration of beneficial agents along with other technological tools and suppressive strategies to establish management systems that maximize biological control of pest complexes. Emphasis is on horticultural crops.
Brower, J.H. Stored Product Insects Research and Development Laboratory P.O. Box 22909 Savannah, GA 31403 Phone: 912-233-7981 FTS: 248-4408	Develops new knowledge and improved control principles for using natural enemies of stored-product insects more effectively. Specifically: Evaluates the effectiveness of indigenous parasites and predators for management of stored-product pest populations and develops technology for establishing or augmenting natural enemy populations in farm storage and commercial storages. Emphasis is currently placed on insect parasites of these pests.
Burkholder, W.E. Stored Product Insects Research Unit Dept. Entomology, Univ. of WI Madison, WI 53706 Phone: 608-262-3795 FTS: 364-5148	Develop new knowledge and improved control principles for using natural enemies more effectively. Specifically: utilizes semiochemicals to manipulate parasitoids and to manipulate host insects to pathogen sources. Studies biology, behavior, and physiology of parasitoids and identifies semiochemicals from parasitoids and hosts to improve management of stored product insects.
Cantelo, W.W. Vegetable Laboratory B-470, BARC-E Beltsville, MD 20705 Phone: 301-344-4557 FTS: 344-4557	Evaluate native and foreign parasitic nematodes as control agents for flies attacking commercial mushrooms. Develop methodology to obtain maximum efficacy.
Carlson, R.W. Systematic Entomology Laboratory Bldg. 003, BARC-W Beltsville, MD 20705 Phone: 301-344-4450 FTS: 344-4450	To develop a catalog of the Ichneumonidae of the United States and provide taxonomic identification and information on these wasps.
Carruthers, R.I. Plant Protection Research Unit Boyce Thompson Institute Tower Road Ithaca, NY 14853 Phone: 607-257-2030 FTS: none	Develops new knowledge and principals associated with the population dynamics of insect pathogens and their use as biological control agents; develops qualitative and quantitative models of population processes; and conducts specific research on the biological control of grasshopper and leafhoppers.
Charlet, L.D. Oilseeds Research Unit 1605 West College St. Fargo, ND 58105 Phone: 701-237-5771, 5625 FTS: 783-5625	Parasitoid fauna and rates of parasitism in cultivated sunflower will be documented. Abundance, behavior, and parasitization rate will be studied in the field and biology determined in the laboratory. Insects are the banded sunflower moth and the sunflower stem weevil.
Cohen, A.C. Biological Control of Insects Laboratory 2000 E. Allen Rd. Tucson, AZ 85719 Phone: 602-629-6220 FTS: 762-6220	Development of basic and applied knowledge to allow in vitro rearing of key species of predaceous insects, with special attention to hemipterous predators. This research includes the study of dietary, nutritional, and physical requirements of predaceous insects.

Cordo, H.A. Biological Control of Weeds Laboratory, South America 1559 So. Bolivar Hurlingham, Buenos Aires, Arg Phone: 011-54-1-665-0357	Survey for, collection, study, and shipment of natural enemies of weed and insect pests in South America.
Coudron, T.A. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	Fundamental research on the chemistry involved in the interaction of biological control agents and agricultural pest insects. Toxins, endocrine and semiochemical substances are studied and their mode of action delineated. Euplectrus spp.and Nomuraea rileyi are used as the model beneficial agents.
Coulson, J.R. Beneficial Insects Laboratory Rm. 211, Bldg. 476, BARC-E Beltsville, MD 20705 Phone: 301-344-1748 FTS: 344-1748	Develops and maintains the ARS Biological Control Documentation Center, and U.S. National Voucher Collection of Introduced Beneficial Arthropods. Develops data base on importation and release of beneficial organisms in the U.S. and territories (ROBO) and other biocontrol data bases. Provides technical advice for ARS biological control importation activities involving Federal, State, and foreign laboratories. Cooperates in coordination of ARS biological control programs through membership on various ad hoc groups and through national documentation activities.
Dame, D.A. Insects Affecting Man and Animals Research Laboratory P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5930 FTS: 947-7930	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators, parasites, and pathogens for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of mosquitoes.
Day, W.H. Beneficial Insects Research Laboratory 501 S. Chapel St. Newark, DE 19713 Phone: 302-731-7330 FTS: 487-6095	Develop practical biological control program for two mirid pests of alfalfa and other crops, continue analysis and publication of data from multi-faceted, long-term alfalfa weevil biocontrol project (current savings to agriculture and consumers $50 million/year), and advise APHIS on their extension of this work.
Debolt, J.W. Biological Control of Insects Laboratory 2000 E. Allen Rd. Tucson, AZ 85719 Phone: 602-629-6220 FTS: 762-6220	Basic and applied research on behavior, physiology and genetics of native and exotic entomophagous arthropods in the laboratory and field to develop more efficient strains and devise better use strategies thereby enhancing their efficiency against pests.
Devaney, J.A. Veterinary Toxicology and Entomology Research Laboratory P.O. Drawer GE College Station, TX 77841 Phone: 409-260-9450 FTS: 527-1405	Develop new biological and ecological knowledge for use in integrated control of external parasites of range livestock. Evaluate the potential use of an indigenous fungi for control of various lice on cattle.
Doane, W.M. Plant Polymer Research Laboratory 1815 N. University St. Peoria, IL 61604 Phone: 309-685-4011 FTS: 360-4556	Developing starch matrixes for encapsulating Bt, viruses and microsporidians for control of European corn borer. Emphasis is being placed on protecting entomopathogens from ultraviolet and other environmental degradations.

Dolphin, R.E.
Yakima Agricultural Research Laboratory
3706 W. Nob Hill Blvd.
Yakima, WA 98902
Phone: 509-575-5980
FTS: 446-5980

Studies the ecological life histories of the natural enemies of insects that inflict economic damage to deciduous fruit orchards and vegetable plantings to enhance insect control. Pear psylla is a pest being investigated.

Dougherty, E.M.
Insect Pathology Laboratory
Rm. 214, Bldg. 011A, BARC-W
Beltsville, MD 20705
Phone: 301-344-3692
FTS: 344-3692

Develops new knowledge and improved efficacy of a nuclear polyhedrosis virus of the gypsy moth, *Lymantria dispar*; specifically studies the replication and genetics of the virus and the virus-cell and virus-host interaction to optimize the virus as a control agent.

Drea, J.J.
Beneficial Insects Laboratory
Bldg. 406, BARC-E
Beltsville, MD 20705
Phone: 301-344-1791
FTS: 344-1791

Development of criteria to increase successful release and establishment of natural enemies with special emphasis for needs of large scale action regulatory programs in biological control. Develop an acceptable protocol for introducing exotic nematodes into the U.S. within an expanding program directed toward using nematodes in biological control. Conduct studies on established and introduced natural enemies of scale insects of ornamental, nursery, vegetable, and fruit trees to evaluate established species and increase control of these pests through additional introductions. Develop classical biological control for weeds of of pasture and noncropland areas, specifically, thistles and purple loosestrife; introduce, establish, and evaluate arthropod natural enemies of these weeds.

Dulmage, H.T.
Subtropical Crop Insects Research Unit
P.O. Box 1033,
424 Ringold Road
Brownsville, TX 78520
Phone: 512-542-2516
FTS: 529-2514

Develops new knowledge and improved screening procedures for discovering new or more potent microbial insecticides. Specifically: Evaluates the activity of microbial agents against various fruit fly species. Emphasis is on strains of *Bacillus thuringiensis*.

Dunkle, R.L.
Plant Polymer Research Laboratory
1815 N. University St.
Peoria, IL 61604
Phone: 309-685-4011
FTS: 360-4542

Developing starch matrixes for encapsulating Bt, viruses and microsporidians for control of European corn borer. Emphasis is being placed on protecting entomopathogens from ultraviolet and other environmental degradations.

Dysart, R.J.
Beneficial Insects Research Laboratory
501 S. Chapel Street
Newark, DE 19713
Phone: 302-731-7330
FTS: 487-6095

Conducts basic and applied research on natural enemies of *Sitona* and *Hypera* weevils in alfalfa. Major emphasis is placed on importation and colonization of exotic beneficial species towards biological control. Also involved in development and enlargement of a computer-based data bank for storage and retrieval of all beneficial organisms handled by the BIRL quarantine facility. Serves as principal ARS advisor providing technical guidance to the APHIS-PPQ Biological Control Program against the alfalfa weevil and their aphid predator program.

Elliott, N.C. Northern Grain Insects Research Laboratory Rural Route #3 Brookings, SD 57006 Phone: 605-693-5212 FTS: none	Biological control research consists of evaluation of indigenous predators of cereal aphids and incorporation of observed predator-prey relationships into systems models. The models are used both for research to determine the role of predators in cereal aphid population dynamics and ultimately to more effectively incorporate predators into cereal aphid management systems. Future work may also include evaluation of imported coccinellid beetles.
Elsey, K.D. U.S. Vegetable Laboratory 2875 Savannah Highway Charleston, SC 29407 Phone: 803-556-0840 FTS: none	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of *Diabrotica* using nematode parasites.
Faust, R.M. Insect Pathology Laboratory Rm. 214, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-4327 FTS: 344-4327	The isolation and identification of insect pathogens and their toxins with particular reference to bacteria such as *Bacillus thuringiensis*, *B. popilliae*, and *B. sphaericus*; the elucidation of the genetic factors controlling their biochemical and pathological properties necessary for the genetic improvement and development of novel strains; the establishment of their biological relationships, mode of action, and biochemistry; the factors necessary for their successful use; and the development of materials and methods for economic production by commercial companies.
Ferkovich, S.M. Insect Attractants, Behavior, and Basic Biology Research Laboratory P.O. Box 14565 1700 SW 23rd Dr. Gainesville, FL 32604 Phone: 904-374-5767 FTS: 947-7767	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Investigates physiological and biochemical interactions between insect parasites and their hosts with an emphasis on developmental biology of larval endoparasites of *Heliothis*. Develops in vitro culture techniques toward facilitating eventual artificial rearing capabilities.
Fincher, G.T. Veterinary Toxicology and Entomology Research Laboratory P.O. Drawer GE College Station, TX 77841 Phone: 409-260-9336 FTS: 527-1336	Determines effects of exotic and native species of competitors and predators on dung-breeding pest flies of livestock. Specifically: Introduces, colonizes, lab evaluates, mass-rears, releases, and field evaluates (with native species) exotic species of dung beetles and predators for horn fly control.
Fuester, R.W. Beneficial Insects Research Laboratory 501 S. Chapel St. Newark, DE 19713 Phone: 302-731-7330 FTS: 487-6095	Basic and applied research on natural enemies of the gypsy moth (GM) and other insect pests of trees. Importation, release, and evaluation of exotic natural enemies of GM. Field studies on population dynamics of GM and its natural enemies. Modeling attack rates of dominant natural enemies of GM.
Gentry, C.R. Southeastern Fruit and Tree Nut Research Laboratory P.O. Box 87 Byron, GA 31008 Phone: 912-956-5656 FTS: 238-0421	Surveys natural enemies of white peach scale.

Goodwin, R.H. Rangeland Insects Laboratory Montana State Univ. Bozeman, MT 59717 Phone: 406-994-3344 FTS: 585-4909	Develops new knowledge for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous pathogens (viruses) for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of grasshoppers.
Gordon, R.D. Systematic Entomology Laboratory c/o US National Museum Natural History Washington, DC 20560 Phone: 202-382-1792 FTS: 382-1792	To develop new classifications of lady beetles and dung-feeding scarab beetles; specifically working on a major cooperative project on the lady beetles of South America and another project on the dung-feeding aphodiine beetles of the U.S., and provide taxonomic identifications and information on lady beetles and scarabs.
Greany, P.D. Insect Attractants, Behavior, and Basic Biology Research Laboratory 1700 SW 23rd Dr. P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5763 FTS: 947-7763	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Investigates physiological and biochemical interactions between insect parasites and their hosts with an emphasis on developmental biology of larval endoparasites of *Heliothis*. Develops in vitro culture techniques toward facilitating eventual artificial rearing capabilities.
Greenstone, M.H. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	Development of monoclonal antibodies and enzyme-linked immunosorbent assays for the detection and quantitative study of arthropod predation and parasitism. Special emphasis on predation by spiders and ecological processes determining spider species diversity in agroecosystems, including aerial dispersal and the influence of three-dimensional structure of vegetation.
Grissell, E.E. Systematic Entomology Laboratory c/o US National Museum Natural History Washington, DC 20560 Phone: 202-382-1781 FTS: 382-1781	Develops new knowledge on the systematics of parasitic wasps. Specifically: evaluates relationships of parasites worldwide; summarizes biological, taxonomic, and geographical information; provides authoritative identifications for other workers. Emphasis is on groups with demonstrated effectiveness in biocontrol.
Gross, H.R. Insect Biology and Population Management Research Laboratory P.O. Box 748 Tifton, GA 31794 Phone: 912-382-6904 FTS: none	Investigate the biology, ecology, and behavior of southern grain insects (primarily corn earworm, *Heliothis zea*, and fall armyworm, *Spodoptera frugiperda*) to identify factors that critically influence their life and seasonal cycles, geographic distribution and dispersal, as well as the biotic and abiotic factors that influence the presence, numbers, and efficiency of their associated entomophages. The ultimate goal is the integration of research findings into insect pest management systems that are efficient, economical, and impact least on the environment in general and on beneficial species in particular.
Gruber, F. European Parasite Laboratory c/o American Embassy, Agr. APO New York Behoust, France 09777 Phone: 011-3313-487-2075 FTS: none	Survey for, study, evaluate, collect, and ship natural enemies of insect pests in Europe, the Near East, and North Africa.

Hackett, K.J.
Insect Pathology Laboratory
Bldg. 465, BARC-East
Beltsville, MD 20705
Phone: 301-344-3086
FTS: 344-3086

Evaluates the effectiveness of pathogens for control of insects.

Hagstrum, D.W.
Biological Research Unit
1515 College Ave.
Manhattan, KS 66502
Phone: 913-776-2718
FTS: none

Current research is an investigation of the quantitative response of insect populations to environmental factors and management practices. Natural parasite populations are an important factor influencing the growth rate of insect pest populations. Knowledge of the impact of parasites on pest population is, therefore, necessary to understand and predict insect pest population dynamics.

Halfhill, J.E.
Yakima Agricultural Research Laboratory
3706 West Nob Hill Blvd.
Yakima, WA 98902
Phone: 509-575-5877
FTS: 446-5877

Determine ecology and behavior of pests as related to their natural enemies, plant hosts, and the physical environment. Develop pest management systems emphasizing modification of cultural practices and augmentation of natural enemies.

Hamm, J.J.
Insect Biology and Population Management Research Laboratory
P.O. Box 748
Tifton, GA 31794
Phone: 912-382-6904
FTS: none

Basic and applied studies of insect pathogens that infect insects attacking grain in the South and development of strategies for their microbial control. Current emphasis on developmental cycles, host range, and virulence of viruses and microsporida, their potential use in suppression of populations of fall armyworm and corn earworm, and interactions between pathogens and parasitoids.

Harris, E.J.
Tropical Fruit and Vegetable Research Laboratory
2727 Woodlawn Dr.
Honolulu, HI 96822
Phone: 808-988-2158
FTS: none

Development of basic and applied knowledge on development rates and survival in different types of fruit, influence of host fruits and habitats on the ecology of *Biosteres* parasites. Develop techniques and approaches to remove constraints to mass productions, and develop efficient strains for biological control of tephritids, especially the Mediterranean fruit fly.

Hart, W.G.
Subtropical Crop Insects Research Unit
P.O. Box 267
Weslaco, TX 78596
Phone: 512-565-2423
FTS: none

Develop new approches for introduction of natural enemies of fruit flies. Specifically: Evaluates the usefulness of parasite species that have proven effective on other fruit flies on *Anastrepha* spp. of concern of subtropical fruit and the possible impact on the postharvest situation.

Heath, R.R.
Insect Attractants, Behavior, and Basic Biology Research Laboratory
1700 SW 23rd Dr., Box 14565
Gainesville, FL 32604
Phone: 904-374-5735
FTS: 947-7735

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Isolates, identifies semiochemicals that mediate oviposition in parasitoids and develops methods to use them to develop in vitro rearing methods.

Heilman, M.D.
Conservation and Production Systems Research Unit
P.O. Box 267
Weslaco, TX 78596
Phone: 512-969-2511
FTS: none

Utilizing pest management practices that combine biological and chemical control of increasing cotton production efficiency, reducing environmental impacts when used in conjunction with short-season cotton production strategies.

Hendrickson, R.M.
Beneficial Insects Research Laboratory
501 S. Chapel St.
Newark, DE 19713
Phone: 302-731-7330
FTS: 487-6095

Conducts basic and applied research on natural enemies of potato leafhopper on alfalfa, and two species of asparagus beetles. Major emphasis is on importation and colonization of exotic foreign natural enemies.

Henry, J.E.
Rangeland Insects Laboratory
Montana State University
Bozeman, MT 59717
Phone: 406-994-3344
FTS: 585-4909

Accelerated development of entomopoxviruses for control of rangeland grasshoppers, with emphasis on producing safety and efficacy testing, dosages, and methods of formulation and application.

Henry, T.J.
Systematic Entomology Laboratory
c/o US National Museum
Washington, DC 20560
Phone: 202-382-1780
FTS: 382-1780

To develop new classifications of predaceous mirid bugs and stilt bugs; provide taxonomic identifications and information on all true bugs including minute pirate bugs, damsel bugs, stinkbugs, and predaceous plant bugs.

Herard, F.
European Parasite Laboratory
c/o American Embassy-Agr.
APO New York
Behoust, France 09777
Phone: 011-3313-487-2075
FTS: none

Survey for, study, evaluate, collect, and ship natural enemies of insect pests in Europe, the Near East, and North Africa.

Hewitt, G.B.
Rangeland Insects Laboratory
Montana State University
Bozeman, MT 59717
Phone: 406-994-3344
FTS: 585-4909

Determines factors that affect grasshopper development and mortality in the northern mixed prairie region. Emphasis is on grasshopper ecology, primarily factors that affect survival of eggs.

Hopper, K.R.
Southern Field Crop Insect Management Laboratory
P.O. Box 346
Stoneville, MS 38776
Phone: 601-686-2311
FTS: 497-2279

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous parasites and predators for pest management decision-making, and develops knowledge necessary for augmenting natural enemy populations. Emphasis is on management of Heliothis spp.

Hoyer, H.
European Parasite Laboratory
c/o American Embassy-Agr.
APO New York
Behoust, France 09777
Phone: 011-3313-487-2075
FTS: none

Survey for, study, evaluate, collect, and ship natural enemies of insects pests in Europe, the Near East, and North Africa.

Hsu, H.T.
Florist and Nursery Crops Laboratory
Rm. 108, Bldg. 004, BARC-W
Beltsville, MD 20705
Phone: 301-344-2013
FTS: 344-2013

Develop methods to monitor gypsy moth cytoplasmic polyhedrosis and nuclear polyhedrosis viruses; develop serological reagents and techniques for CPV detection; develop techniques for CPV identification by genomic RNA analysis; evaluate and compare rabbit antiserum and monoclonal antibodies for NPV assays.

Humber, R.A.
Plant Protection Research Unit
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853
Phone: 607-257-2030
FTS: none

Conducts basic research on the systematics and developmental biology of entomopathogenic fungi (particularly those of the Entomophathorales); curates a collection of entomopathogenic fungal cultures (currently numbering ca. 900 active strains), and provides diagnosis upon request for the complete spectrum of entomopathogenic fungi. Special emphasis is placed on studies of phylogeny and nuclear cytology in the Entomophthorales.

Hung, A.C.F. Beneficial Insects Laboratory Bldg. 476, BARC-E Beltsville, MD 20705 Phone: 301-344-1779 FTS: 344-1749	Develops and adapts biochemical, cytological, and immunological technologies to evolutionary genetics as applied to biosystematics of parasitic Hymenoptera in support of biological control programs.
Ignoffo, C.M. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	Develop, modify, and enhance the effectiveness of microbials against destructive insects via problem solving research on: the pathogen; its host; the environment; and interactions between these 3 components. The NPV of *Heliothis* and the fungus *Nomuraea rileyi* are models for this research.
Jackson, C.G. Biological Control of Insects Laboratory 2000 East Allen Road Tucson, AZ 85719 Phone: 602-629-6220 FTS: 762-6220	Evaluates the impact of native and introduced parasites and predators on populations of insect pests and develops ways to improve their effectiveness. Specific areas of research include the development of laboratory rearing procedures; the development and evaluation of sampling methods for entomophagous insects; determining parasite-host or predator-prey relationships, habitat preference, and seasonal population dynamics; determining the effect ofphysical environmental factors on the development, survival, reproductive potential, and other biological and behavioral characteristics of entomophagous insects.
Jackson, D.M. Tobacco Research Laboratory P.O. Box 1555 Oxford, NC 27565 Phone: 919-693-5151 FTS: 672-3111	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous and exotic predators, parasites, and pathogens for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of *Heliothis* and *Manduca* spp. in tobacco.
Jackson, J.J. Northern Grain Insects Research Laboratory Rural Route #3 Brookings, SD 57006 Phone: 605-693-5205 FTS: none	Identify and improve the efficacy of pathogens and parasites for the biological control of *Diabrotica* spp. Specifically: Evaluate and develop control systems using entomogenous nematodes and protozoa for population control of the corn rootworm complex, especially the western corn rootworm.
Johnson, D.E. Biological Research Unit 1515 College Ave. Manhattan, KS 66502 Phone: 913-776-2724 FTS: none	Investigate the use of microbial pathogens for the protection of stored grain from insect damage. Determine the mechanism of *Bacillus thuringiensis* toxin activation and larval susceptibility/resistance in Indianmeal moths.
Jones, W.A. Biological Control of Insects 2000 East Allen Road Tucson, AZ 85719 Phone: 602-629-6220 FTS: 762-6220	Dr. Jones will not arrive at this laboratory until 9/1/87. His specific areas of research will be determined after that time.

Jouvenaz, D.P.
Insects Affecting Man and Animals Research Laboratory
1700 SW 23rd Dr.
P.O. Box 14565
Gainesville, FL 32604
Phone: 904-374-5989
FTS: 947-7989

Investigates biocontrol of fire ants, with emphasis on pathogens. Immediate objectives are to 1) discover and describe the specific pathogen biota of fire ants, 2) develop methods of culture, 3) investigate pathobiology in all aspects, including potential for genetic manipulation, and 4) assess the safety and biocontrol potential of these organisms.

Keever, D.W.
Tobacco Research Laboratory
P.O. Box 1555
Oxford, NC 27565
Phone: 919-693-5151
FTS: 672-3111

Evaluates the potential of pathogens and their toxins against insect pests of stored commodities. Emphasis is on stored tobacco; the cigarette beetle and tobacco moth; and thuringiensin and new strains of Bt. Candidate materials are examined for dose response, residual activity, and sublethal effects.

Kemp, W.P.
Rangeland Insects Laboratory
Montana State University
Bozeman, MT 59717
Phone: 406-994-6473
FTS: 585-4909

The broad area of research is insect community ecology, with strong emphasis on the role of parasites and predators in determining grasshopper population dynamics. The specific assignment requires characterization and modeling of population dynamics, ecological roles, and interrelationships concerning grasshoppers, parasites, predators, and the environment. Problems include development of sampling techniques, identification of insects and host plants, instrumentation to record environmental conditions, insect rearing, and experimental design. Incumbent also provides ecological, mathematical, and computer expertise to a research team on integration of chemical, cultural, and biological tactics for management of grasshoppers and other insect pests of rangeland.

Kieckhefer, R.W.
Northern Grain Insects Research Laboratory
Rural Route #3
Brookings, SD 57006
Phone: 605-693-5215
FTS: none

Research on biological control currently involves detailed analysis of the impact of coccinelid predators on cereal aphid populations. Specifically, we are evaluating predator searching rates as those rates are influenced by physical environmental factors, hunger, and searching patterns. Results of research will be incorporated into systems analysis model.

King, E.G.
Subtropical Agricultural Research Laboratory
P.O. Box 267
Weslaco, TX 78596
Phone: 512-565-2423
FTS: none

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of *Heliothis* and boll weevil.

Klein, M.G.
Horticultural Insects Research Laboratory
Ohio Agric. Res. & Dev. Ctr.
Wooster, OH 44691
Phone: 216-263-3896
FTS: none

Develop new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous nematodes, pathogens, and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of Japanese beetle and other horticultural pests.

Knutson, L.V.
Beneficial Insects Laboratory
Rm. 1, Bldg. 003, BARC-W
Beltsville, MD 20705
Phone: 301-344-3182
FTS: 344-3182

Development of computerized biosystematic databases on western hemisphere immigrant arthropods, flies of the world, and expert systems for biosystematic data; taxonomic research on snail-killing flies and robber flies; research on biology of snail-killing flies and use as biological control agents.

Kurtzman, C.P. Microbial Properties Research 1815 N. University St. Peoria, IL 61604 Phone: 309-685-4011 FTS: 360-4561	Maintenance of the ARS Culture Collection. Included in the collection are a number of microorganisms used for biological control of insects such as Bacillus thuringiensis.
Lewis, L.C. Corn Insects Research Unit RR, Box 45B Ankeny, IA 50021 Phone: 515-964-6664 FTS: none	Investigates the epizootiology of Beauveria bassiana and Nosema pyrausta. Determines the role of tillage in conserving natural enemies of Ostrinia nubilalis. Investigates the compatability of parasitoids and predators with pathogens of hosts or prey.
Lewis, W.J. Insect Attractants, Behavior, and Basic Biology Research Laboratory P.O. Box 748 Tifton, GA 31793 Phone: 912-382-6904	Develop technology to improve the use of beneficial insects as pest control agents. Emphasis is to understand semiochemical mediated foraging behavior of parasitoids that attack Heliothis spp. and Spodoptera frugiperda, and to develop techniques for applied manipulation of these behaviors.
Lindegren, J.E. USDA Horticultural Crops Research Laboratory 2021 S. Peach Avenue Fresno, CA 93727 Phone: 209-487-5334 FTS: 467-5334	Develops new knowledge and improved control technology for using insect pathogens more effectively. Emphasis is on evaluating the effectiveness of entomogenous nematodes for augmenting the control of navel orangeworm, tephritid fruit flies and other insects of postharvest and quarantine importance.
Lofgren, C.S. Insects Affecting Man and Animals Research Laboratory 1600 SW 23rd Dr. P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5920 FTS: 947-7920	Supervises efforts to discover/utilize biocontrol agents for control of imported fire ants. Specifically, develops research plans and assigns tasks. Assists in interpretations. Research concentrated in Specific Cooperative Agreement with EMBRAPA, at Caceres, Mato Grosso, Brazil, and the ARS lab, Hurlingham, Argentina.
Lopez, J.D. Cotton Insects Research Unit P.O. Drawer DG College Station, TX 77841 Phone: 409-260-9351 FTS: 527-1351	Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for conserving and augmenting natural enemy populations. Emphasis is on management of Heliothis.
Lynn, D.E. Insect Pathology Laboratory Rm. 214, Bldg. 011a, BARC-W Beltsville, MD 20705 Phone: 301-344-4328 FTS: 344-4328	Development of insect cell culture for use in supporting growth of insect viruses and other pathogens. This includes developing new cell lines from previously uncultured insects or from new tissue sources. Also, improvements in media or culture conditions are studied. This includes physiological, developmental, and nutritional aspects of insect cells in culture.
Manglitz, G.R. Forage and Range Research Unit 305 Plant Ind. Dept. Ent. Univ. of NE Lincoln, NE 68583 Phone: 402-471-5267 FTS: 541-5267	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of introduced parasites for decision-making technology. Emphasis is on management of alfalfa weevil.
Marsh, P.M. Systematic Entomology Laboratory c/o U.S. National Museum Washington, DC 20560 Phone: 202-382-1782 FTS: 382-1782	To develop new classifications of parasitic wasps of the family Braconidae, particularly in the genera Rogas and Heterospilus and in subfamilies Doryctinae and Rogadinae; prepare identification manual for North American braconid genera; provide taxonomic identifications and information on Braconidae, Aphidiidae and Proctotrupoidea.

Martin, P.A.W. Insect Pathology Laboratory Rm. 214, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-4331 FTS: 344-4331	Environmental microbiology to understand the role of Bt in natural ecosystems leading to methods to develop highly efficacious insect control agents.
McGaughey, W.H. Biological Research Unit 1515 College Ave. Manhattan, KS 66502 Phone: 913-776-2705 FTS: none	Investigate the use of microbial pathogens for the protection of stored grain from insect damage. Determine the mechanism of _Bacillus thuringiensis_ toxin activation and larval susceptibility/resistance in Indianmeal moth. Investigate the quantitative response of stored grain insect populations to environmental factors and management practices. Parasites, predators, and pathogens are important factors influencing the growth of these populations. Knowledge of their impact is necessary to understand and predict pest population dynamics.
McGuire, M.R. Rangeland Insects Laboratory Montana State University Bozeman, MT 59717 Phone: 406-994-3344 FTS: 585-4909	Develops new methods for diagnosing pathogens of insects. Specifically monoclonal antibody-based enzyme-linked immunosorbent assays are developed for detecting entomopoxviruses in grasshoppers. Propagates, releases, and recovers entomopoxvirus in rangeland grasshopper populations. Evaluates impact of virus on population density.
McIntosh, A.H. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	Currently involved in the characterization and identification of baculoviruses; genetic stability of viral genomes; establishment of new insect cell lines and their identification by isoelectric focusing; in vitro specificity of baculoviruses; cellular resistance to baculoviruses.
McLaughlin, R.E. Insects Affecting Man and Animals Research Laboratory P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5906 FTS: 947-7906	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of exotic and indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of mosquitoes.
Menke, A.S. Systematic Entomology Laboratory c/o U.S. National Museum Natural History Washington, DC 20560 Phone: 202-382-1803 FTS: 382-1803	To develop new classifications of primarily predaceous wasps of the family Sphecidae, particulatly in the genus _Larra_ which is parasitic on mole crickets; provide taxonomic identifications and information on aculeate wasps.
Moore, R.F. European Parasite Laboratory c/o American Embassy-Agr. APO New York Behoust, France 09777 Phone: 011-3313-487-2075	Survey for, study, evaluate, collect, and ship natural enemies of insect pests in Europe, the Near East, and North Africa.
Moreno, D.S. Subtropical Crop Insects Research Unit P.O. Box 267 Weslaco, TX 78596 Phone: 512-565-2647 FTS: none	Develop new information on the parameters of parasitoid viability as determined by availability, density and size of hosts, intra- and interspecific competition, quality of host and meteorological conditions. Specifically: Evaluates the effectiveness of imported parasitoids on _Anastrepha_ and develops information to enhance parasitoid management.

Morgan, P.B.
Insects Affecting Man and Animals Research Laboratory
P.O. Box 14565
Gainesville, FL 32604
Phone: 904-374-5903
FTS: 947-7903

Develop new knowledge and improve control principles for using natural enemies of muscoid flies and cockroaches most effectively. Specifically: Evaluate the effectiveness of parasites in integrated systems to suppress wild population of muscoid flies. To augment natural enemy populations with exotic or improved strains of indigenous parasites.

Morrison, R.K.
Cotton Insects Research Unit
P.O. Drawer DG
College Station, TX 77841
Phone: 409-260-9353
FTS: 527-1353

Develops new knowledge and principles for more effective production and utilization of natural enemies of insect pests. Specifically: Evaluate new methods (in vitro and in vivo) for production, storage, and release of entomophages. Emphasis is on management of Heliothis spp.

Neal, J.W.
Florist and Nursery Crops Laboratory
Bldg. 470, BARC-E
Beltsville, MD 20705
Phone: 301-344-4559
FTS: 344-4559

Develops new knowledge on predator-prey synchrony. Specifically: Studies the biology of a monophagous mirid predator of the azalea lace bug to determine host plant mechanisms that regulate egg hatch and results in delayed synchrony.

Nettles, W.C.
Cotton Insects Research Unit
P.O. Drawer DG
College Station, TX 77841
Phone: 409-260-9351
FTS: 527-1351

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Develops technology for in vitro production and augmentation of natural enemy populations. Emphasis is on management of Heliothis.

Nickle, W.R.
Systematic Botany, Mycology, and Nematology Laboratory
Bldg. 264, BARC-E
Beltsville, MD 20705
Phone: 301-344-3064
FTS: 344-3064

Conducts basic and applied research on the taxonomy, biology, life cycles, rearing and utilization of insect parasitic nematodes to control pest soil insects. Current emphasis is on nematode parasites of corn rootworms, Colorado potato beetles, mushroom flies, and taxonomic research on the pinewood nematode.

Nordlund, D.A.
Cotton Insects Research Unit
P.O. Drawer DG
College Station, TX 77841
Phone: 409-260-9351
FTS: 527-1351

Conducts research on the behavior and ecology of entomophagous insects, with emphasis on semiochemicals, to improve their performance and effectiveness in periodic release and environmental manipulation programs for control of Heliothis and other insect pests.

Nyczepir, A.P.
Southeastern Fruit and Tree Nut Research Laboratory
P.O. Box 87
Byron, GA 31008
Phone: 912-956-5656
FTS: 238-0421

Nematodes are being evaluated as control agents for the pecan weevil. This research is in cooperation with entomologists.

Onsager, J.A.
Rangeland Insects Laboratory
Montana State University
Bozeman, MT 59717
Phone: 406-994-3944
FTS: 585-4909

Develops selective formulations and proper timing of chemicals and pathogens for control of rangeland grasshoppers in order to minimize direct impacts on nontarget parasites and predators, which requires supporting research in phenology and population dynamics of both pest and beneficial species.

Pair, S.D.
Insect Biology and Population Management Research Laboratory
P.O. Box 748
Tifton, GA 31793
Phone: 912-382-6904
FTS: none

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of fall armyworm and Heliothis spp.

Patana, R. Biological Control of Insects Laboratory 2000 E. Allen Rd. Tucson, AZ 85719 Phone: 602-629-6220 FTS: 762-6220	Basic and applied research on the ecology and biological control of Lygus and other Hemiptera, with emphasis on the development of rearing systems for the pests and their parasites and predators,
Patterson, R.S. Insects Affecting Man and Animals Research Laboratory P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5903 FTS: 947-7903	Develop new knowledge and improve control principles for using natural enemies of muscoid flies and cockroaches most effectively. Specifically: Evaluate the effectiveness of parasites in integrated systems to suppress wild population of muscoid flies and cockroaches. To augment natural enemy populations with exotic or improved strains of indigenous parasites.
Petersen, J.J. Livestock Insects Research Unit 305 Plant Industry Bldg. University of Nebraska Lincoln, NE 68583 Phone: 402-471-5267 FTS: 541-5267	Develop new and improve existing biological control methods for house flies and stable flies. Specifically: Develop effective control strategies for the use of pteromalid wasps at confined livestock installations in the midwest and to isolate and characterize naturally occurring pathogens and parasites of these flies.
Powell, J.E. Southern Field Crop Insect Management Laboratory P.O. Box 346 Stoneville, MS 38776 Phone: 601-686-2311 FTS: 497-2267	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of Heliothis.
Press, J.W. Stored Product Insects Research and Development Laboratory 3401 Edwin Street. P.O. Box 22909 Savannah, GA 31403 Phone: 912-233-7981 FTS: 248-4408	No activity statement provided.
Puttler, B. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	Conducts basic and applied research on the biological control of insects. Emphasis, when possible, is placed on complete programs, starting with exploration, introduction, rearing, release, and biological studies (e.g., temperature relationships, fecundity, longevity, diapause, sex ratios, host feeding). Surveys for establishment, dispersal, and evaluation are also conducted. Present research is connected with two parasites (Cotesia rubecula and Hyposoter ebenenus) of the imported cabbage worm collected and introduced from Yugoslavia. Both these species are better adapted to the host than C. glomerata established 100 years ago.
Raulston, J.R. Subtropical Crop Insects Research Unit P.O.Box 1033 Brownsville, TX 78520 Phone: 512-542-2516 FTS: none	Develops new methodology for biological control of Heliothis. Specifically: Evaluates the impact of indigenous parasites and predators.

Reed, D.K. Asian Parasite Laboratory c/o American Embassy APO San Francisco Seoul, South Korea Phone: 011-8202-963-6561 FTS: none	Cooperates with researchers in the U.S. by assisting in discovery, evaluations and shipments of beneficial species of insects or microorganisms. Cooperates with Korean scientists in biological, microbiological, ecological research on organisms and target species which are either common to both countries or those indigenous to Korea but posing a threat to American agriculture or forestry.
Roach, S.H. Cotton Production Research Unit P.O. Box 2131 Florence, SC 29503 Phone: 803-669-6664 FTS: none	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of *Heliothis*.
Robacker, D.C. Subtropical Crop Insects Research Unit P.O. Box 267 Weslaco, TX 78596 Phone: 512-565-2647 FTS: none	Develop method for matching populations of predators and parasites to populations of pest species to achieve maximum control. Specifically: Evaluates biochemical methods to identify similarities and differences in population genetics of beneficial and pest insects. Emphasis is on citrus pests.
Rogers, C.E. Insect Biology and Population Management Research Laboratory P.O. Box 748 Tifton, GA 31793 Phone: 912-382-6904 FTS: 230-6444	Develop new knowledge and improved principles for using natural enemies of insects more effectively. Specifically: Determines the host-range for *Noctuidema guyanensis* (a nematode) and its pathogenicity to the fall armyworm, *Spodoptera frugiperda*.
Roth, J.P. Veterinary Toxicology and Entomology Research Laboratory P.O. Drawer GE College Station, TX 77841 Phone: 409-260-9326 FTS: 527-1326	Develop new knowledge and improved control principles for management of insects affecting range livestock. Specifically: Determine compatability of control methods (chemical and managerial) with pupal parasitoids of dung-breeding Diptera in nonaccumulated (pasture) manure.
Schaefer, P.W. Beneficial Insects Research Laboratory 501 S. Chapel ST. Newark, DE 19713 Phone: 302-731-7330 FTS: 487-6095	Conducts basic and applied research on exotic natural enemies of the Mexican bean beetle, gypsy moth, and various aphid pests. Major emphasis is on quarantine evaluation of potentially beneficial species and on foreign exploration (especially in Orient). Field releases of successful candidate species then necessitate surveys designed to confirm if establishment has occurred.
Schalk, J.M. U.S. Vegetable Laboratory 2875 Savannah Highway Charleston, SC 29407 Phone: 803-556-2210 FTS: 677-4746	Investigate the use of nematodes, *Filipjevimermis leipsandra*, *Neoplectana* sp. and *Heterorhabditis* sp., for the control of root worms (*Diabrotica* sp., and *Acalymma* sp.) and cutworms attacking vegetable crops.
Schauff, M.E. Systematic Entomology Laboratory c/o National Museum NHB 168 Washington, DC 20560 Phone: 202-382-1784 FTS: 382-1784	Develops new knowledge on the systematics of parasitic wasps. Specifically: Evaluates relationships of parasites worldwide; summarizes biological, taxonomic, and geographical information; provides authoritative identifications for other workers. Emphasis is on groups with demonstrated effectiveness in biocontrol.

Schroder, R.F.W. Beneficial Insects Laboratory Bldg. 476, BARC-E Beltsville, MD 20705 Phone: 301-344-2369 FTS: 344-2369	Develop new technology and improved control principles for using natural enemies of insects more effectively. Specifically: Develops technology for integration of introduced biocontrol agents into pest management systems and the resultant transfer of technology to action agencies and industries. Current emphasis is on management of Colorado potato beetle on potato, eggplant, and tomato.
Schroeder, W.J. Entomology and Nematology Research Unit 2120 Camden Road Orlando, FL 32803 Phone: 305-897-7306 FTS: 822-9306	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of *Verticillium lecanii*, entomogenous nematodes, and insect parasites for developing technology for augmenting natural enemy populations. Emphasis is on management of citrus and other horticultural crop pests.
Shapiro, M. Insect Pathology Laboratory Rm. 214, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3864 FTS: 344-3864	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Conducts research to maintain and optimize persistence and activity of entomopathogenic viruses. Emphasis is on the gypsy moth, *Lymantria dispar*.
Shasha, B.S. Plant Polymer Research Laboratory 1815 N. University ST. Peoria, IL 61604 Phone: 309-685-4011 FTS: 360-4310	Developing starch matrixes for encapsulating Bt, viruses and microsporidians for biocontrol of European corn borer. Emphasis is being placed on protecting entomopathogens from ultraviolet and other environmental degradations. Performs chemical aspects of this research.
Shaver, T.N. Cotton Insects Research Unit P.O. Drawer DG College Station, TX 77841 Phone: 409-260-9351 FTS: 527-1351	Conducts research on the behavior and ecology of parasites and predators with emphasis on semiochemicals to improve their establishment and effectiveness in periodic releases.
Smiley, R.L. Systematic Entomology Laboratory Rm. 2, Bldg. 004, BARC-W Beltsville, MD 20705 Phone: 301-344-3891 FTS: 344-3891	Taxonomic research on beneficial mites. Specifically: Identify and describe new mite taxa in support of ongoing research with Forest Service, that are candidates for the biological control of forest insects. Developing a new knowledge on the predatory mite family Cunaxidae for controlling orchard and greenhouse pests.
Soper, R.S. Plant Protection Research Unit Boyce Thompson Institute Tower Road Ithaca, NY 14853 Phone: 607-257-2030	Involved in basic research on epizootiology of the grasshopper pathogen *Entomophaga grylli*; participates in exploration for new strains of insect-attacking fungi; research on fungal pathogen of gypsy moth.
Sosa Jr., O. Sugarcane Production Research Unit Star Route, Box 8 Canal Point, FL 33438 Phone: 305-924-5227 FTS: None	Investigate insect parasitic nematodes as biological control organisms of white grubs in sugarcane. Specifically, evaluates efficacy of nematode species in parasitising Ligyrus subtropicus, under laboratory and small field plot conditions.

Sparks, A.N. Insect Biology and Population Management Research Laboratory P.O. Box 748 Tifton, GA 31793 Phone: 912-382-6904 FTS: None	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous and exotic predators and parasites for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of fall armyworm and *Heliothis* spp.
Steiner, W.W.M. Biological Control of Insects Research Laboratory P.O. Box 7629 Research Park Columbia, MO 65205 Phone: 314-875-5361 FTS: 276-5361	To genetically characterize entomophagous arthropod predators and parasites, seek ways to use the genetic knowledge to enhance entomophage beneficence and develop genetically-enhanced strains for augmentation and IPM releases.
Summy, K.R. Subtropical Crop Insects Research Unit P.O. Box 267 Weslaco, TX 78596 Phone: 512-565-2647 FTS: None	Develops new methodology for biological control of boll weevil. Specifically: Evaluates impact of exotic and indigenous parasites.
Sumner, H.R. Insect Biology and Population Management Research Laboratory P.O. Box 748 Tifton, GA 31793 Phone: 912-382-6904 FTS: none	Identify, develop, and employ principles and techniques for the safe, efficient and economical management of primary insect pests of production agriculture through the conveying of biological control agents in irrigation water and by conventional application methodology. Emphasis will be placed on *Heliothis zea* and *Spodoptera frugiperda*.
Tedders, W.L. Southeastern Fruit and Tree Nut Research Laboratory P.O. Box 87 Byron, GA 31008 Phone: 912-956-5656 FTS: 238-0421	Biological control systems for pecan insects, particularly the pecan weevil and aphids, are being developed. The research is driven by aphid resistance to pesticides and the high cost of pecan production. Vetch is planted in orchards which supplies natural predator and parasite populations to control early aphids. Additional releases of lady beetles and lace wing larvae are being evaluated as an augmentation procedure to the natural predation. Biological control of pecan weevils is being investigated by using nematode and disease organisms.
Temeyer, K.B. U.S. Livestock Insects Labortory P.O. Box 232 Kerrville, TX 78029 Phone: 512-257-3566 FTS: None	Plans and conducts studies related to the evaluation and genetic engineering of entomopathogens for development of novel biological pesticides. Emphasis is on use of *Bacillus thuringiensis* for management of *Haematobia irritans* (horn fly).
Thompson, F.C. Systematic Entomology Laboratory c/o U.S. National Museum Washington, DC 20560 Phone: 202-382-1800 FTS: 382-1800	Develops new knowledge for using enemies of insects more effectively. Develops new approaches for distributing biosystematic information to user groups. Specifically: Studies various predaceous or phytophagous flower flies as well as accumulates and distributes information on all flies.
Tompkins, G.J. Insect Pathology Laboratory Rm. 214, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3690 FTS: 344-3690	Developing methods for increasing virulence of baculouviruses for biocontrol purposes and means of protecting these agents from degradation in the natural environment to improve their effectiveness. Characterizing by biochemical and serologic techniques rickettsial like organisms and viruses.

Tumlinson, J.H.
Insect Attractants, Behavior, and Basic Biology Research Laboratory
1700 SW 23rd Drive
P.O. Box 14565
Gainesville, FL 32604
Phone: 904-374-5730
FTS: 947-7731

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Isolates, identifies, synthesizes and evaluates semiochemicals mediating behavior of parasitoids; develops technology for using semiochemicals to enhance the efficacy of parasitoids for biological control. Emphasis is on management of *Heliothis*.

Undeen, A.H.
Insects Affecting Man and Animals Research Laboratory
P.O. Box 14565
Gainesville, FL 32604
Phone: 904-374-5944
FTS: 947-7944

Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Evaluates the effectiveness of indigenous and exotic pathogens for decision-making technology and develops technology for augmenting natural enemy populations. Emphasis is on management of mosquitoes.

Vail, P.V.
USDA Horticultural Crops Research Laboratory
2021 S. Peach Ave.
Fresno, CA 93727
Phone: 209-487-5334
FTS: 467-5334

Develops new knowledge and strategies for control of postharvest pests utilizing insect pathogens and the advantages of the postharvest environment. Pathogens will be isolated, produced, and characterized and evaluated as to virulence, efficacy, persistence under laboratory and storage conditions.

Vargas, R.I.
Tropical Fruit and Vegetable Research Laboratory
2727 Woodlawn Dr.
Honolulu, HI 96822
Phone: 808-988-2158

Collects data on distribution and abundance of fruit fly parasites for development of eradication procedures in Hawaii. Improves mass rearing capabilities for augmentative parasite releases.

Vaughn, J.L.
Insect Pathology Laboratory
Rm 214, Bldg. 011A, BARC-W
Beltsville, MD 20705
Phone: 301-344-3688
FTS: 344-3688

Develops new systems for the culture of insect cells, studies virus infection and multiplication in cell cultures in order to capitalize on the new molecular biology. Laboratory studies for the development of cell cultures to produce insect viruses commercially.

Webb, R.E.
Florist and Nursery Crops Laboratory
Bldg. 470, BARC-E
Beltsville, MD 20705
Phone: 301-344-4562
FTS: 344-4562

Develops new knowledge and improved control principles for using natural enemies more effectively. Specifically: Evaluates the effect of applied pesticides on the gypsy moth natural enemy complex, releases microsporidia against gypsy moth, and elucidates the relationship between a gypsy moth parasite and its hyperparasites.

Whitcomb, R.F.
Insect Pathology Laboratory
Bldg. 465, BARC-E
Beltsville, MD 20705
Phone: 301-344-2339
FTS: 344-2339

Evaluates the effectiveness of pathogens for control of insects and studies the ecology of leafhopper vectored plant diseases with the goal of interrupting disease transmission. Emphasis is on management of insect vectors of plant disease.

Williams, D.F.
Insects Affecting Man and Animals Research Laboratory
1700 SW 23rd Drive
P.O. Box 14565
Gainesville, FL 32604
Phone: 904-374-5991
FTS: 947-7991

Develop new knowledge and discover new natural enemies of insects. Specifically: Search for effective predators and parasites and develop the technology for using these natural enemies against populations of the imported fire ant *Solenopsis invicta*.

Wojcik, D.P. Insects Affecting Man and Animals Research Laboratory 1600 SW 23rd Drive P.O. Box 14565 Gainesville, FL 32604 Phone: 904-374-5921 FTS: 947-7921	Develops new knowledge and improved control principles for using natural enemies of insects more effectively. Specifically: Participates in foreign exploration for natural enemies of fire ants and their introduction and release from quarantine including basic systematic, biological, and ecological studies. Emphasis is on management of imported fire ants.
Wolfenbarger, D.A. Subtropical Crop Insects Research Unit P.O. Box 267 Weslaco, TX 78596 Phone: 512-565-2647 FTS: None	Develops post-harvest treatments and methods of detecting fruit flies in various subtropical fruit. Specifically: Evaluates role of pesticides in host-parasite environment. Emphasis is on Tephritidae fruit flies.
Wong, T.T.Y. Fruit Fly Biology and Control Research Unit P.O. Box 2280 Honolulu, HI 96804 Phone: 808-988-2158 FTS: None	Conducts basic and applied research to improve mass production of fruit fly parasitoids. Laboratory and field evaluation of efficacy of the parasitoids. Inundative releases of parasitoids alone and in conjunction with sterile insect release method to suppress and eradicate fruit fly populations.
Woodley, N.E. Systematic Entomology Laboratory c/o U.S. National Museum NHB 168 Washington, DC 20560 Phone: 202-382-1802 FTS: 382-1802	Taxonomy and evolution of tachinid flies (Diptera: Tachinidae) parasitic on other insects and arthropods, especially moths and beetles. Specific genera are *Belvosia*, *Parachytas*, and *Gymnocheta*, all parasites of moth larvae.
Yokomi, R.K. Entomology and Nematology Research Unit 2120 Camden Road Orlando, FL 32803 Phone: 305-897-7306 FTS: 822-9306	Evaluates *Verticillium beanii* for effectiveness in controlling insect pests of citrus and other horticultural crops.
Young, J.R. Insect Biology and Population Management Research Laboratory P.O. Box 748 Tifton, GA 31793 Phone: 912-382-6904 FTS: none	Identify, develop, and employ principles and techniques for the safe, efficient, and economical management of primary insect pests ofproduction agriculture through the conveying of biological control agents in irrigation water and by conventional application methodology. Emphasis will be placed on *Heliothis zea* and *Spodoptera frugiperda*.
Zimmerman, D.C. Oilseeds Research Unit 1605 West College St. Fargo, ND 58105 Phone: 701-237-5771 FTS: 783-5625	Parasitoid fauna and rates of parasitism in cultivated sunflower will be documented. Abundance, behavior, and parasitization rate will be studied in the field and biology determined in the laboratory. Insects are the banded sunflower moth and the sunflower stem weevil.

Profiles of ARS Scientists Researching Biological Control of Plant Pathogen and Nematode Pests

Adams, P.B. Soilborne Diseases Laboratory Rm. 267, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3080 FTS: 344-3080	Develop basic and applied knowledge on the use of mycoparasites for control of diseases caused by soilborne fungi. Specialized areas of research include the interaction of <u>Sporidesmium sclerotivorum</u> and its host in soil, the biotic and abiotic factors which affect this interaction, and other research required for the development of this fungus into a practical biological control agent.
Albach, R.F. Conservation and Production Systems Research Unit USDA-ARS P.O.Box 267 Weslaco, TX 78596 Phone: 512-969-2511	Develop new knowledge of phytotoxic compounds in weed and crop plants or their residues and to determine their mode of allelopathic action in subtropical cropping systems; and to suggest principles and methods to employ the new body of knowledge for novel and practical means of improving crop productivity.
Anderson, L.W.J. Aquatic Weed Control Research Unit Botany Dept., Univ. of CA Davis, CA 95616 Phone: 916-752-6260 FTS: none	Develops new knowledge on the feeding preference and effectiveness of triploid grass carp for management of aquatic weeds in western water storage and conveyance systems. Determines potential for combinations of grass carp, competitive plants and use of selective herbicides to manage aquatic weeds. Investigates relationship between aquatic weed consumption by grass carp, weed nutrient content and factors which alter feeding preference.
Baker, C.J. Microbiology and Plant Pathology Laboratory Rm. 252, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3617 FTS: 344-3617	The overall objective of our project is to understand the physiological/biochemical basis for host-pathogen recognition involved in natural and induced resistance. Induced resistance involves the use of an avirulent pathogen to protect plants by triggering plant defense mechanisms.
Bills, D.D. Plant Science Research Unit 600 E. Mermaid Lane Philadelphia, PA 19118 Phone: 215-233-4178 FTS: 489-6580	Isolate, identify, characterize, and synthesize naturally occurring chemicals (allelopathic compounds) that are produced by weeds and crop or or forage plants. Determine the effect of naturally occurring phytotoxic chemicals on the suppression of weed growth.
Bovey, R.W. Grassland, Soil, and Water Research Laboratory Dept. Range Science Texas A&M Univ. College Station, TX 77843 Phone: 409-260-9238 FTS: 527-1238	Develops new knowledge and weed control methods in newly established forage crops with herbicides/plant competitors or combination of these methods to allow seedling growth and survival of kleingrass, buffelgrass, and other forages on pastures and rangeland.
Civerolo, E.L. Fruit Laboratory Rm. 120, Bldg. 004, BARC-W Beltsville, MD 20705 Phone: 301-344-3569 FTS: 344-3569	Develops new knowledge using phages and antagonistic bacteria to control bacterial plant diseases. Identify and evaluate the effectiveness of phages and phylloplane bacteria as antagonists against xanthomonads. Develop technology for in planta establishment/augmentation of these agents.
Comes, R.D. Weed, Soil, and Water Management Research Unit P.O. Box 30 Prosser, WA 99350 Phone: 509-786-3454 FTS: none	Develop new knowledge and improved control principles and practices for establishing and maintaining desirable vegetation under different soil moisture conditions. Specifically: Evaluates the ability of grasses to establish and compete with weedy vegetation and determines their response to herbicides. Emphasis is on management of reed canarygrass and a host of annual weeds.

Cook, R.J.
Root Disease and Biological Control Research Unit
Washington State Univ.
367 Johnson Hall
Pullman, WA 99164
Phone: 509-335-3722

Develops new knowledge of ecology of soilborne pathogens of wheat and barley and their antagonists as they interact with these crop plants, and from this knowledge develops controls using cultural practices and strategic introductions.

Domir, S.C.
Nursery Crops Research Laboratory
359 Main Road
Delaware, OH 43015
Phone: 614-363-1129
FTS: 975-9347

Isolate and identify naturally occurring xylem-colonizers of maples and elms that demonstrate antagonistic or competitive interaction with vascular pathogens. Study modes of action between antagonist and pathogens to determine their nature or enhance activity in vivo. Study host-pathogen interaction using tissue culture technology.

Farr, D.F.
Systematic Botany, Mycology, and Nematology Laboratory
Room 313, Bldg. 011A, BARC-W
Beltsville, MD 20705
Phone: 301-344-3364
FTS: 344-3364

Develops computerized databases of fungal organisms useful as biocontrol agents including their host and geographical distribution. Provides accurate systematic information about these fungi.

Farr, M.L.
Systematic Botany, Mycology, and Nematology Laboratory
Rm. 313, Bldg. 011a, BARC-W
Beltsville, MD 20705
Phone: 301-344-3364
FTS: 344-3364

Discovers potential of slime molds as biocontrol agents of soilborne pathogens through cultural experiments in the laboratory. Contributes to the computerized databases of fungal organisms useful as biocontrol agents.

Fravel, D.R.
Soilborne Diseases Laboratory
Rm. 275, Bldg. 011A, BARC-W
Beltsville, MD 20705
Phone: 301-344-3653
FTS: 344-3653

Develops new knowledge about parameters influencing the proliferation and establishment of biocontrol fungi in the rhizosphere and the influence of these parameters on extracellular metabolites which mediate biocontrol. Develops new knowledge about the mechanisms of biocontrol of antagonistic fungi used to control soilborne plant pathogenic fungi. This knowledge is used to genetically improve the biocontrol agent. Emphasis is on the use of Talaromyces flavus to control Verticillium dehliae.

Gough, F.J.
Crop Production and Water Conservation Research Laboratory
P.O. Box 1029
Stillwater, OK 74076
Phone: 405-624-4126
FTS: 728-4126

Develops new knowledge for enhancing and maintaining population densities of disease-suppressing epiphytic bacteria. Specifically: Evaluates wheat genotypes for ability to support naturally occurring microorganisms antagonistic to foliar pathogens.

Harrison, H.F.
U.S. Vegetable Laboratory
2875 Savannah Highway
Charleston, SC 29407
Phone: 803-556-0840
FTS: none

Develop knowledge of the allelopathic effects of sweet potatoes on weeds. Isolates allelochemicals for subsequent identification by chemists, and characterizes the effect of allelopathy on crop-weed interference. Investigated the potential use of Platysenta sutor for control of Eclipta alba.

Howell, C.R.
Cotton Pathology Research Unit
P.O. Drawer JF
College Station, TX 77841
Phone: 409-260-9234
FTS: 527-1234

Develops new knowledge of the mechanisms involved in the biocontrol process. Isolates and identifies active metabolites from biocontrol agents. Enhances the efficacy of promising biocontrol agents by classical genetic techniques and genetic engineering.

Janisiewicz, W.J. Appalachian Fruit Research Station Route 2, Box 45 Kearneysville, WV 25430 Phone: 304-725-3451 FTS: none	Develops biological control of postharvest diseases of pome fruits. Specifically: Isolates antagonists against *Pencillium expansum*, *Botrytis cinerea* and *Mucor piriformis* from pome fruits. Studies their ecology, mode of action, effectiveness on fruit and compatibility with postharvest treatments and storage conditions.
Kraft, J.M. Vegetable and Forage Crops Research Production Unit P.O. Box 30 Prosser, WA 99350 Phone: 509-786-2226 FTS: none	Develops new knowledge and improved control principles for using antagonists and/or competitors of soil-borne root pathogens of edible legumes, including peas, chickpeas, and beans. Methods of application include seed treatments, in furrow application (granular and liquid).
Krause, C.R. Nursery Crops Research Laboratory 359 Main Road Delaware, OH 43015 Phone: 614-363-1120 FTS: none	Isolate and identify naturally occurring xylem-colonizers of maples and elms that demonstrate antagonistic or competitive interaction with vascular pathogens. Study modes of action between antagonist and pathogens to determine their nature or enhance activity in vivo. Study host-plant pathogen interaction using tissue culture technology.
Leath, K.T. U.S. Regional Pasture Research Laboratory Curtin Road University Park, PA 16802 Phone: 814-863-0939 FTS: none	Studies use of bacteria to control fungal diseases of forage legumes.
Leather, G.R. Foreign Disease-Weed Science Research Unit Fort Dietrick, Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7132 FTS: 935-7132	The research involves the study of plant-produced allelochemicals that interfere with the growth of other plants. Specifically, the identification and development of systems that can utilize allelopathic crop plants that interfere with the growth of weeds, and the determination of the physiological and biochemical effects of allelochemicals on susceptible plant species.
Lewis, J.A. Soilborne Diseases Laboratory Rm. 281, Bldg. 011a, BARC-W Beltsville, MD 20705 Phone: 301-344-3056 FTS: 344-3056	Acquire knowledge on environmental and ecological factors affecting soilborne plant pathogens and their antagonists; develop and formulate biocontrol preparations; evaluate biocontrol agents for disease and pathogen reduction; develop integrated pest management systems using biological and cultural methods in association with innovative fungicide application approaches; study effect of organic matter on effectiveness of biocontrol agents.
Linderman, R.G. Horticultural Crops Research Laboratory 3420 NW Orchard Ave. Corvallis, OR 97330 Phone: 503-757-4544 FTS: 420-4544	Develops new knowledge and improved technology relative to biological control of root diseases of plants through management of microbes in the rhizosphere, especially mycorrhizal fungi and rhizobacteria.

Locke, J.C. Florist and Nursery Crops Laboratory Rm. 108, Bldg. 004, BARC-W Beltsville, MD 20705 Phone: 301-344-2413 FTS: 344-2413	Evaluation of the efficacy of biocontrol agents in soilless growing media to control major damping-off pathogens (Pythium and Rhizoctonia) resulted in a single isolate of Gliocladium virens (G-20) being selected for intensive study. Formulation technology with this isolate has been the major thrust, concentrating on nutrient substrate and carrier amendments. This research is conducted in cooperation with the Soilborne Diseases Laboratory and scientists at the W. R. Grace Company. Bioassay of these formulations is being carried out on both seedling crops in soilless media and bench crops in "natural" soil. The results of this work will provide a basis for evaluation of additional biocontrol agents which will be developed for other target pathogens with reduced pesticide usage.
Loper, J.E. Horticultural Crops Research Laboratory 3420 NW Orchard Ave. Corvallis, OR 97330 Phone: 503-757-4544 FTS: 420-4544	Identifies the physiological and genetic basis of interactions observed among beneficial microorganisms and between beneficial and pathogenic microorganisms in the rhizosphere.
Lumsden, R.D. Soilborne Diseases Laboratory Rm. 262, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3679 FTS: 344-3679	Conducts basic and applied research on the biological, cultural, and integrated control of soilborne plant pathogens. Specifically, in relation to Pythium spp., Rhizoctonia solani, and Sclerotinia spp., studies the survival of these pathogens in agricultural soils, their association with antagonistic microorganisms in soil, and the ability of antagonists to control diseases caused by these pathogens. Studies means by which disease suppression can be enhanced by addition of organic amendments, encouragement of the activity of antagonistic microorganisms, or integration of disease control means for maximum crop productivity.
Meyer, R.E. Systematic Botany, Mycology, and Nematology Laboratory Rm. 313, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3364 FTS: 344-3364	Develops new knowledge and understanding of systematic relationships of Trichoderma species useful in biological control of soilborne diseases. Mitochondrial and nuclear nucleic acids are analyzed and correlated with morphological characters.
Mircetich, J.S.M. Crops Pathology and Genetics Research Unit Dept. Plant Pathology Univ. California Davis, CA 95616 Phone: 916-752-1919	Develops new knowledge and control principles for fruit and nut tree diseases caused by NEPO (nematode-transmitted polyhedral viruses) viruses. Specifically: Evaluates the effectiveness of satellite tobacco ringspot virus RNA in controlling blackline disease in English walnut trees caused by cherry leafroll virus.
Mischke, B.S. Soilborne Diseases Laboratory Rm. 275, Bldg. 011A, BARC-W Beltsville, Md 20705 Phone: 301-344-4003 FTS: 344-4003	Develops new knowledge about characteristics of biocontrol fungi and develops techniques to manipulate these characteristics. Current techniques under development are protoplast methodology and recombinant DNA technology.
Panasiuk, O. Plant Science Research Unit 600 E. Mermaid Lane Philadelphia, PA 19118 Phone: 215-233-6423 FTS: 489-6423	Isolate, identify, characterize, and synthesize naturally occurring chemicals (allelopathic compounds) that are produced by weeds and crop or forage plants. Determine the effect of naturally occurring phytotoxic chemicals on the suppression of weed growth.

Papavizas, G.C. Soilborne Diseases Laboratory Rm. 274, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3682 FTS: 344-3682	Research on biological, cultural, and integrated control of economically important soilborne plant diseases including use of microorganisms and environmental modifications in control; development of basic and applied knowledge to improve the efficiency of biocontrol agents; research to acquire fundamental knowledge on soil environmental factors that affect survival of pathogens and biocontrol agents in soil, and determine specific interactions that occur among soilborne pathogens, host plants, and associated microorganisms.
Pusey, P.L. Southeastern Fruit and Tree Nut Research Laboratory P.O. Box 87 Byron, GA 31008 Phone: 912-956-5656 FTS: 238-0421	The fungal organism <u>Bacillus subtilis</u> is being evaluated as a biological control for brownrot of peaches. Particular emphasis is being placed on the control of brownrot in postharvest situations. Results have been very promising.
Rossman, A.Y. Systematic Botany, Mycology, and Nematology Laboratory Rm. 313, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3364 FTS: 344-3364	Explores exotic habitats for microbial biocontrol agents of soilborne foliar diseases and weeds and conducts studies on their systematic relationships for predicting usefulness.
Sayre, R.M. Nematology Laboratory Rm. 152, Bldg. 011A, BARC-W Beltsville, MD 20705 Phone: 301-344-3039 FTS: 344-3039	Development of basic and applied knowledge to improve methods for the biological control of plant nematode diseases with maximum beneficial effects on crop yield and quality, and minimum of undesirable effects on the environment. Emphasis on development of microbiological techniques to locate, identify, propagate, and evaluate diseases and antagonists of nematodes.
Schreiber, L.R. Nursery Crops Research Laboratory 359 Main Road Delaware, OH 43015 Phone: 614-363-1129 FTS: 975-9347	Isolate and identify naturally occurring xylem-colonizers of maples and elms that demonstrate antagonistic or competitive interaction with vascular pathogens. Study modes of action between antagonist and pathogens to determine their nature or enhance activity in vivo. Study host-pathogen interaction using tissue culture technology.
Spencer, D.F. Aquatic Weed Control Research Unit University of California Davis, CA 95616 Phone: 916-752-6260 FTS: none	Develops new knowledge and improved control principles for using beneficial competitive plants to suppress weed growth in irrigation systems. Specifically, identifies through experimentation the factors which limit growth of dwarf spikerish (<u>Eleocharis</u>); develops methods for enhancing its growth.
Spurr Jr., H.W. Tobacco Research Laboratory P.O. Box 1555 Oxford, NC 27565 Phone: 919-693-5151 FTS: 672-3111	Develop knowledge of biological control for foliar pathogens of tobacco and other crops. Study physical and biological parameters of phyllosphere, determine impact on interactions of microorganism, identify and develop superior antagonists to foliar pathogens, and develop methods to introduce and manage antagonists on phylloplane for disease control.
Stipanovic, R.D. Cotton Pathology Research Unit P.O. Drawer JF College Station, TX 77841 Phone: 409-260-9234 FTS: 527-1234	Develops new knowledge of the mechanisms involved in the biocontrol process. Isolates and identifies biologically active metabolites from biocontrol agents and determines biosynthetic pathways.

Stretch, A.W. Appalachian Fruit Research Station B&C Res. Center Penn State Forest Road Chatsworth, NJ 08019 Phone: 609-726-1590 FTS: None	Develops new knowledge and improved control principles for using natural enemies of disease producing fungi. Evaluates the effectiveness of indigenous bacteria, etc., for decisionmaking technology and develops technology for augmenting natural enemy populations. Emphasis is on fruit rotting fungi.
Thomas, M.D. Cotton Pathology Research Unit P.O. Drawer JF College Station, TX 77841 Phone: 409-260-9233 FTS: 527-9233	Develops new knowledge and improved control by augmenting the efficacy of biological control organisms. Specifically a genetic exchange system is being developed to identify and introduce beneficial traits into the biocontrol fungus *Gliocladium roseum*.
Thomashow, L.S. Root Disease and Biological Control Research Unit Washington St. University 367 Johnson Hall Pullman, WA 99164 Phone: 509-335-3722 FTS: None	Develops new knowledge of genetics of biological control agents and systems and uses this knowledge to test hypothesis on mechanisms and to improve the biocontrols.
Vakili, N.G. Cereal and Soybean Improvement Research Unit Dept. Plant Pathology Rm. 411, Bessey Hall Ames, IA 50011 Phone: 515-294-8412 FTS: None	Reduce infection, suppress disease, and increase yield in corn by combining mycoparasite tolerance with resistance to stalk rot pathogens. Develop highly parasitic strains of mycoparasites. Control infestation by European corn borer. Reduce chemical use in seed treatment.
Weller, D.M. Root Disease and Biological Control Research Unit Washington State University 367 Johnson Hall Pullman, WA 99164 Phone: 509-335-3722 FTS: None	Develops new knowledge of rhizosphere microbiology and wheat root-microbe associations with potential to protect wheat roots against disease
Wilson, C.L. Appalachian Fruit Research Station Route 2, Box 45 Kearneysville, WV 25430 Phone: 304-725-3451 FTS: None	Develop new, nonpesticide means of controlling diseases of pome fruit, stone fruit, blueberries, and cranberries. Specifically: Establish and utilize antagonists of postharvest pathogens, cross-protection, induced resistance, hyparasitism, and ecological manipulations to control fruit diseases.
Wisniewski, M.E. Appalachian Fruit Research Station Route 2, Box 45 Kearneysville, WV 25430 Phone: 304-725-3451 FTS: None	Cytological and physiological research on the mode of action of biocontrol agents using both in vitro and in vivo systems. Research centers on the use of fungal and bacterial antagonists for the control of disease important to the tree-fruit industry.

Profiles of ARS Scientists Researching Biological Control of Terrestrial and Aquatic Weed Pests

Anderson, D.M. Systematic Entomology Laboratory c/o National Museum Natural History Washington, DC 20560 Phone: 202-382-1794 FTS: 382-1794	Develops, synthesizes, and disseminates information on larvae of lady beetles and some weevil pests and of the weevil genus *Smicronyx* (adults). Some lady beetles and a few *Smicronyx* species are of significance as active or potential biocontrol agents.
Anderson, L.W.J. Aquatic Weed Control Research Unit Botany Dept., Univ. of CA Davis, CA 95616 Phone: 916-752-6260 FTS: none	Develops new knowledge on the feeding preference and effectiveness of triploid grass carp for management of aquatic weeds in western water storage and conveyance systems. Determines potential for combinations of grass carp, competitive plants and use of selective herbicides to manage aquatic weeds. Investigates relationship between aquatic weed consumption by grass carp, weed nutrient content and factors which alter feeding preference.
Andres, L.A. Biological Control of Weeds Research Unit 800 Buchanan St. Albany, CA 94710 Phone: 415-486-3684 FTS: 449-3684	Identify and evaluate weed feeding arthropods for host specificity and potential control value, and clear, release and evaluate these control candidates in the United States. Develop strategies to increase stresses on weedy plants.
Boldt, P.E. Grassland, Soil, and Water Research Laboratory P.O. Box 6112 Temple, TX 76503 Phone: 817-774-1201 FTS: 736-1201	Develop principles and technology for the utilization of imported natural enemies of weeds, especially insects. Introduce, test in quarantine and release candidate biological control agents and evaluate establishment, distribution, and impact in the field. Determine the ecology of native natural enemies and their effects on target weeds.
Boyette, C.D. Southern Weed Science Laboratory P.O. Box 350 Stoneville, MS 38776 Phone: 601-686-2311 FTS: 497-2217	Develops new knowledge and improved control principles for using pathogens of weeds more effectively. Specifically: discovers and evaluates weed pathogens and integrated weed management systems and develops technology to' improve the culturing efficacy, and host range of the pathogens. Emphasis is on management of troublesome weeds in field crops.
Bruckart, W.L. Foreign Disease-Weed Science Research Unit Ft. Dietrick, Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7344 FTS: 935-7344	Collects, identifies, and evaluates plant pathogens for biological control of introduced weed species in North America. Specific research involves rust fungal pathogens of *Carduus* spp., *Centaurea* spp., and *Cyperus* spp.
Buckingham, G.R. Aquatic Weed Control Res. Unit P.O. Box 1269 Gainesville, FL 32602 Phone: 904-372-3505 FTS: None	Conducts basic and applied research on insects that attack aquatic weeds; specialized areas of research include host range testing in quarantine of exotic insects that are candidates for biocontrol, and biology and behavior studies of insects already released for biocontrol.
Cardina, J. Nematodes, Weeds, and Crops Research Unit P.O. Box 748 Tifton, GA 31793 Phone: 912-386-3351	Discover and evaluate fungal pathogens for biological control of weeds, particularly leguminous weeds in peanuts and soybeans. Develop knowledge on environmental response and histopathology for use in strain selection and formulation development.

Center, T.D. Aquatic Weed Control Research Unit 3205 SW Avenue Fort Lauderdale, FL 33314 Phone: 305-475-0541 FTS: none	Develop information and methodology to implement biocontrol of weeds in aquatic and wetland sites. Coordinate and direct foreign surveys for biocontrol agents and release and evaluate approved species in integrated management programs. Conduct studies on insect/plant interrelationships to facilitate development of weed management theories.
Connick, W.J. Composition and Properties Research Unit 1100 Robert E. Lee Blvd. P.O. Box 19687 New Orleans, LA 70179 Phone: 504-286-4527 FTS: none	Devises formulations such as invert emulsions or others based on polymers to prolong the contact of water on plant surfaces to reduce the dew period needed for infection and control of weeds by plant pathogens. Prepares stable, biodegradable formulations of biocontrol organisms such as fungi and nematodes. Maximizes use of agricultural surplus or waste products as formulation adjuvants. Establishes cooperative, interdisciplinary research efforts to improve biocontrol formulations.
Cordo, H.A. Biological Control of Weeds Laboratory, South America 1559 So. Bolivar Hurlingham, Buenos Aires, Arg Phone: 011-54-1-665-0357	Survey for, collection, study, and shipment of natural enemies of weed and insect pests in South America.
Coulson, J.R. Beneficial Insects Laboratory Rm. 211, Bldg. 476, BARC-E Beltsville, MD 20705 Phone: 301-344-1748 FTS: 344-1748	Develops and maintains the ARS Biological Control Documentation Center, and U.S. National Voucher Collection of Introduced Beneficial Arthropods. Develops data base on importation and release of beneficial organisms in the U.S. and territories (ROBO) and other biocontrol data bases. Provides technical advice for ARS biological control importation activities involving Federal, State, and foreign laboratories. Cooperates in coordination of ARS biological control programs through membership on various ad hoc groups and through national documentation activities.
Daigle, D.J. Composition and Properties Research Unit 1100 Robert E. Lee Blvd. P.O. Box 19687 New Orleans, LA 70179 Phone: 504-286-4382	Devises formulations such as invert emulsions or others based on polymers to prolong the contact of water on plant surfaces to reduce the dew period needed for infection and control of weeds by plant pathogens. Prepares stable, biodegradable formulations of biocontrol organisms such as fungi and nematodes. Maximizes use of agricultural surplus or waste products as formulation adjuvants. Establishes cooperative, interdisciplinary research efforts to improve biocontrol formulations.
DeLoach, C.J. Grassland, Soil, and Water Research Laboratory P.O. Box 6112 Temple, TX 76503 Phone: 817-774-1201 FTS: 736-1201	Introduce foreign phytophagous organisms to control native and introduced rangeland weeds; prioritize weeds for research, resolve conflicts of interest, determine effects of native phytophages, conduct foreign exploration and test candidate agents; test in quarantine, release, and evaluate results.
Dowler, W.M. Foreign Disease-Weed Science Research Unit Ft. Dietrick, Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7344 FTS: 935-7344	Studies interactions of herbicides and plant growth regulators with fungi for biocontrol of nutsedges.

Drea, J.J. Beneficial Insects Laboratory Bldg. 406, BARC-E Beltsville, MD 20705 Phone: 301-344-1791 FTS: 344-1791	Developing criteria to increase successful release and establishment of natural enemies with special emphasis for needs of action regulatory programs. Develop an acceptable protocol for introducing exotic nematodes in an expanding program directed toward using these nematodes in biocontrol. Conduct studies on established and introduced natural enemies of scale insects of ornamental, nursery, vegetable, and fruit trees and to increase control through additional introductions. Develop classical biocontrol for selected weeds of pasture and noncropland areas, specifically, thistles and purple loosestrife; introduce, establish, and evaluate arthropod natural enemies of these weeds.
Dunn, P.H. Biological Control of Weeds Laboratory, Europe c/o American Embassy APO, New York Rome, Italy 09794 Phone: 011-39-6-648-0140 FTS: none	Survey for, collect and study the host specificity and clear for introduction into the United States, natural enemies of diffuse, spotted, and Russian knapweeds; and musk thistle. Emphasis is on biological control of these weeds.
Fornasari, L. Biological Control of Weeds Laboratory, Europe c/o American Embassy APO, New York Rome, Italy 09794 Phone: 011-39-6-648-0140 FTS: none	Survey for, collects, studies the host specificity and clears for introduction and release in the United States, natural enemies of yellow starthistle (*Centaurea solstitialis*). Emphasis is on biological control of this weed.
Frank, J.R. Foreign Disease-Weed Science Research Unit Ft. Dietrick Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7344 FTS: 935-7344	Investigates the interaction between rust fungi and herbicides in biological control of weeds, specifically evaluating the integration of bentazon and *Puccinia canaliculata* for control of yellow nutsedge (*Cyperus esculentus*).
French, R.C. Foreign Disease-Weed Science Research Unit Ft. Dietrick Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7344 FTS: 935-7344	Studies volatile germination stimulators of spores of pathogens and weed seed. Specifically: Identifying a stimulator from thistle roots which stimulates teliospores of Canada thistle rust, allowing us to achieve the systemic and devastating aecial infection of the shoot for the first time.
Hoagland, R.E. Southern Weed Science Laboratory P.O. Box 350 Stoneville, MS 38776 Phone: 601-686-2311 FTS: 497-2210	Develops new knowledge and improved control principles for using pathogens and phytotoxins more efficaciously against weeds. Specifically: Discovers biochemical mechanisms of resistance to pathogen/phytotoxins, and determine molecular modes of action. Emphasis is on management of troublesome weeds in field crops.
Hodgson, R.H. Foreign Disease-Weed Science Research Unit Fort Dietrick Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7132 FTS: 935-7132	Develops new knowledge and improved control principles for using natural enemies of weeds more effectively. Specifically: Evaluates the effectiveness of indigenous pathogens for decision-making technology and develops technology for use of beneficial plant pathogens. Emphasis is on management of *Abutilon*.

Jurd, L. Plant Protection Research Unit 800 Buchanan St. Albany, CA 94710 Phone: 415-486-3205 FTS: 449-3205	Investigates the chemistry of invasive weeds (Centaurea and Euphorbia species) to elucidate their biology at the molecular level and to determine the basis for their competitive advantage. These data will be used to complement the insect method of biological control as well as the development of other control strategies. Provides leadership of classical biocontrol program.
Maddox, D.M. Biological Control of Weeds Research Unit 800 Buchanan St. Albany, CA 94710 Phone: 415-486-3625 FTS: 449-3684	Identify and evaluate weed feeding arthropods for host specificity and potential control value, and clear, release, and evaluate these control candidates in the United States. Develop strategies to increase stresses on weedy plants.
Pecora, P. Biological Control of Weeds Laboratory, Europe c/o American Embassy APO NY Rome, Italy 09794 Phone: 011-39-6-648-0140	Finds, identifies, conducts host specificity tests and clears for introduction in the United States, arthropod natural enemies of leafy spurge.
Pemberton, R.W. Biological Control of Weeds Research Unit 800 Buchanan St. Albany, CA 94710 Phone: 415-486-3991 FTS: 449-3991	Discover and evaluate weed feeding arthropods for weed control in the United States. Basic studies on plant arthropod relations including: herbivory, extra floral nectaries, domatia and myrmecochory.
Quimby, P.C. Southern Weed Science Laboratory P.O. Box 350 Stoneville, MS 38776 Phone: 601-686-2311 FTS: 497-2243	Develops new knowledge and improved control principles for using pathogens of weeds more effectively. Specifically: Evaluates interactions of herbicides and weed pathogens in integrated weed management systems and develops technology/formulations for applying weed pathogens in field crops. Emphasis is on management of troublesome weeds in field crops.
Rees, N.E. Rangeland Insects Laboratory Montana State University Bozeman, MT 59717 Phone: 406-994-3344 FTS: 585-4909	No activity statement provided.
Rosenthal, S.S. Biological Control of Weeds Research Unit 800 Buchanan ST. Albany, CA 94710 Phone: 415-486-3624 FTS: 449-3624	Search for, evaluate, determine host specificity plus effectiveness of insects, mites, and nematodes for control of knapweeds. Conduct basic and applied research to determine (1) host plant relationships and guild structure of the knapweed fauna, and (2) how biological weed control may be integrated with other pest control and range management practices.
Smith, R.J. Rice Production and Weed Control Research Unit P.O. Box 287 Stuttgart, AR 72160 Phone: 501-673-2661	Develops new knowledge and improved control principles for using plant pathogens of weeds more effectively. Specifically: Evaluates interactions of weed pathogens with pest management and crop production practices in rice and rotated crops. Emphasis is on control of broadleaf weeds.

Sobhian, R. Biological Control of Weeds Laboratory, Europe c/o American Consulate General APO NY Thessaloniki, Greece 09693 Phone: 011-30-31-47-1581	Survey for, collect, and study the host specificity and clear for introduction into the United States, natural enemies of diffuse, spotted and Russian knapweeds, yellow starthistle, and leafy spurge. Emphasis is on biological control of these weeds.
Thompson, F.C. Systematic Entomology Laboratory c/o U.S. National Museum Washington, DC 20560 Phone: 202-382-1800 FTS: 382-1800	Develops new knowledge for using enemies of insects more effectively. Develops new approaches for distributing biosystematic information to user groups. Specifically: Studies various predaceous or phytophagous flower flies as well as accumulates and distributes information on all flies.
Turner, C.E. Biological Control of Weeds Research Unit 800 Buchanan St. Albany, CA 94710 Phone: 415-486-3310 FTS: 449-3310	Discover and develop weed-feeding stenophagous arthropods for host specificity and potential control value, and release and evaluate the impact of biocontrol arthropods. Develop new significant areas of research in plant-arthropod interactions, including a better understanding of the basis of host patterns in stenophagous arthrpods.
Whitehead, D.R. Systematic Entomology Laboratory c/o U.S. National Museum Washington, DC 20560 Phone: 202-382-1790 FTS: 382-1790	Develops, synthesizes, and disseminates information about the systematics and distributions of weevils (Centrinini, Hylobiina, and Hyperinae), including numerous pest species. Some weevils included herein are biocontrol agents or candidates.
Yang, S.M. Foreign Disease-Weed Science Research Unit Ft. Dietrick, Bldg. 1301 Frederick, MD 21701 Phone: 301-663-7344 FTS: 935-7344	Investigates the use of exotic plant pathogens for biological control of introduced weed species. Currently the target species are leafy spurge (*Euphorbia esula*) and itchgrass (*Rottboellia exaltata*), and the pathogens are, respectively, a systemic rust fungus (*Uromyces* sp.), and a smut fungus.

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